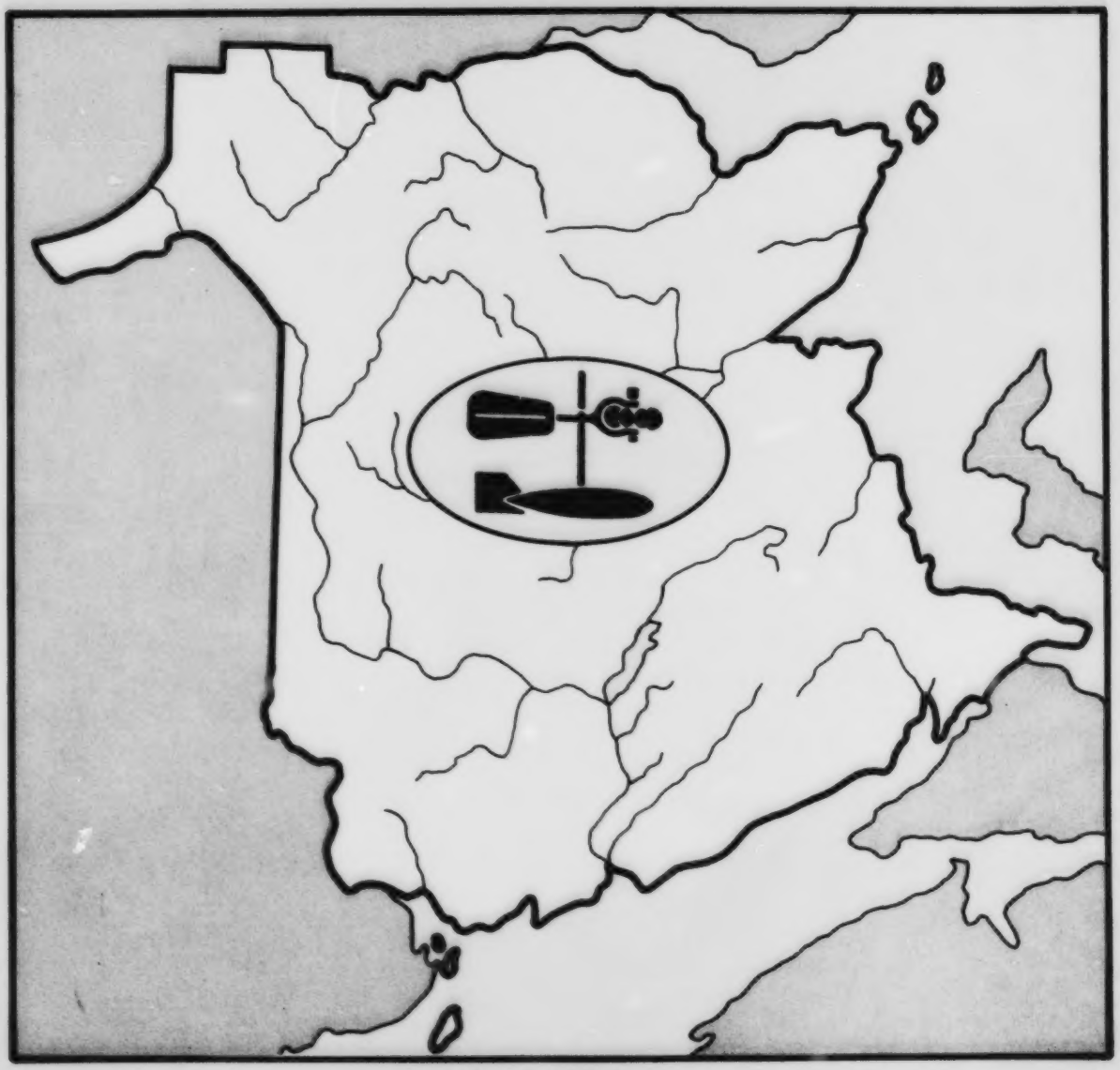
New Brunswick
Hydrometric Network Evaluation

Background Report No. 4
Selected Technological and Operational Issues



April 1988

Environment Canada | Environnement Canada
New Brunswick Department of Municipal Affairs and Environment | Ministère des Affaires Municipales et de L'Environnement du Nouveau-Brunswick

NEW BRUNSWICK HYDROMETRIC NETWORK EVALUATION

BACKGROUND REPORT NO. 4

SELECTED TECHNOLOGICAL AND OPERATIONAL ISSUES

A REPORT PREPARED BY THE
TECHNOLOGY AND OPERATIONS SUBCOMMITTEE
NEW BRUNSWICK HYDROMETRIC NETWORK EVALUATION PROJECT

Environment Canada
Inland Waters/Lands
Water Resources Branch

New Brunswick Department of
Municipal Affairs and
Environment
Water Resource Planning Branch

ABSTRACT

This report reviews selected technological and operational issues in the context of the New Brunswick hydrometric network. The purpose of this review was to determine which instruments or combination of instruments would be the most effective for use in the New Brunswick hydrometric network and to identify operational concerns that should be addressed. The major recommendations reflect a belief that there will be a potential long-term cost saving with increased automation and with the integration of data collection systems; especially the combination of streamflow and water level sensors with sensors to measure water quality and atmospheric parameters.

RESUME

Ce rapport examine certains points techniques et opérationnels se rapportant au fonctionnement du réseau hydrométrique du Nouveau-Brunswick. Il vise fondamentalement à déterminer les appareils qui seraient les plus efficaces aux fins d'exploitation du réseau et à cerner les problèmes qui devraient être traités à cet égard. Si l'on s'en tient aux principales recommandations, l'automatisation accrue et l'intégration des systèmes de collecte de données entraîneront éventuellement des économies à long terme, surtout en ce qui concerne les indicateurs de débit d'un cours d'eau et de niveau d'eau combinés à ceux visant à mesurer la qualité de l'eau et les situations atmosphériques.

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ACKNOWLEDGEMENTS

This report was written by Brian Burrell, Roy Lane and Klaus Wiebe, all of the Technology and Operations Subcommittee.

Gratitude is expressed to Maurice Sydor and Dick Terzi of Environment Canada for the information they provided.

Special thanks are expressed to Lauchlin Murray who helped proofread and compile the first draft of this report.

Thanks also to Don Ambler, John Keefe, Zal Davar, Denis Gingras and Nabil Elhadi who reviewed the draft report.

Mavis Leavitt and Jean Murray are also thanked for their typing.

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MAJOR RECOMMENDATIONS

Major recommendations are those which noticeably affect the cost and accuracy of data from the hydrometric network.

The major recommendations are as follows.

1. Conventional pressure-actuated stage measuring devices (servo-manometers) should no longer be purchased. Strong consideration should be given to the installation of electronic stage sensors and related data acquisition systems at new stations. This will reduce initial capital expenditure and complexity of instrumentation. Accuracy should be increased due to a decrease in loss of record.

2. An installation in New Brunswick of a fixed ultrasonic velocity measurement device should be undertaken within the next three years. This pilot project should include the testing of the device and the training of staff in its operation and maintenance. Special consideration should be given to installation of the device, at a station that could be operated throughout the winter and ice breakup periods. The device, costing approximately $17,000, will provide the necessary field verification of the capability of these instruments to measure flow under difficult conditions, eg. during breakup, and will provide the basis for the eventual operational use of these velocity measurement devices.

3. In view of the National Environmental Satellite Data Information Service (NESDIS) proposal to discontinue direct distribution of data from its Suitland, Maryland location, the Coordinating Committee (of the New Brunswick Hydrometric Network) or their designates should encourage and support Canadian authorities in taking action to ensure its data reception capabilities. This action is now underway with the establishment of two satellite receiving sites in Canada. The support requirements are expected to be confined to the cost of operating these receiving sites; approximately $200. per year per data collection platform.

4. An electronic data acquisition and telemetry system for hydrometeorological data acquisition is currently under development (for Environment Canada). If

evaluation of the system is positive, it is recommended that this system be designated as the standard unit for operational use in the New Brunswick hydrometric network. The system is expected to cost no more than present data acquisition systems, but because of its inherent reliability and flexibility in application, it is expected that its use will reduce data loss and hence improve accuracy.

5. Except for seasonal or event stations, all hydrometric stations should be operated for the period required to define the hydrologic regime. Past experience using conventional instrumentation and procedures indicates that an average of five years is the minimum period required to establish a station producing good quality data at a site. (Conventional refers to technology both in instrumentation and methods presently in widespread use throughout Canada). This will ensure that the data acquired is of value for analytical purposes and can confidently be used to estimate flows at ungauged locations.

6. A normal field survey circuit consists of those stations within a geographical area which are conveniently grouped for visitation. Within the circuit, there may be stations deemed critical for some purpose (eg. flood forecasting). At such stations, satellite data collection platforms should be installed so that station operations can be closely monitored and emergency repairs carried out if necessary.

7. The Coordinating Committee should encourage and support the development of a computer model relating streamflow to actual flow measurements and temperature, precipitation, snowmelt, and hydrograph recession constants. Such a program could be used to provide a less subjective and more scientific interpretation of stream discharges under ice and to improve the quality and timeliness of data provided to users.

8. The Coordinating Committee, or their designates, should further evaluate the potential of fully automating data acquistion at hydrometric stations. Full automation will reduce the need for visitation and will free existing staff to concentrate their efforts on data review and analyses.

9. It is necessary that data at selected sites in Maine be collected using instrumentation suitable for our purposes. However, developments in American and Canadian instrumentation and field procedures are following diverging paths. Therefore, any equipment or instrumentation necessary for flood forecasting or near real-time use should be operated on both sides of the international border by a Canadian agency (such as the Water Survey of Canada) or under formal Agreement with the United States Geological Survey (or their equivalent) for the maintenance of equipment and emergency repairs.

1.0 INTRODUCTION

Water resource management, and increasingly environmental protection, depends upon having an adequate data base of hydrometric information. In order to ensure that sufficient reliable streamflow and water level data are collected in a cost-effective manner, it is necessary to periodically review the hydrometric networks. For New Brunswick, it has been recommended that such a network review be undertaken every five years (Environment Canada and the New Brunswick Department of the Environment, 1979).

The hydrometric network review started in 1986 is intended to provide a cost-effective network design tailored to the needs of users. In deriving this network design, three principal problems are to be addressed:

- a numerical and locational problem of how many stations there should be and where these stations should be located;
- a technology and operations problem of what instrumentation should be used and what procedures should be followed to reliably obtain accurate data; and
- a communications problem of how data can be distributed in various forms to the different user groups for the maximum benefit.

The technology and operations problem, as it relates to hydrometric network planning and design, is discussed in this report.

There are several reasons why consideration of technology and operations is an important component of the current hydrometric network review. Firstly, new technological and operational options have arisen during the past decade. With the rapid development of new instrumentation and progress in the means of data collection, there is greater opportunity to develop hydrometric networks that can provide more comprehensive and varied information more effectively than has been possible before. Secondly, technology and operational procedures directly impact upon the costs of constructing, operating and maintaining a hydrometric network, and hence determine the extent of the net benefits to be obtained. Thirdly, in an increasingly technological environment, user expectations as to the type, accuracy, reliability, and immediacy of

hydrometric data have been evolving due to changing needs for data and more widespread use of computerized data handling packages and hydrologic software. The growth in the demand for real-time data is an example of changing user expectations and requirements. Fourthly, the operating environment of data collection agencies has been altered. Sociological and political pressures for public agencies to reduce expenditures while maintaining or improving their level of service necessitates closer examination of technological and operational options. For example, the sharing of data acquisition instrumentation and communication links among data collection agencies might be a desirable response to the pressure to reduce expenditures within these agencies.

In the design of a hydrometric network, technological and operational concerns are often considered separately from determination of the number and location of stations. To some degree, this approach has been followed in this report. However, the problems are not mutually exclusive and it is intended that the contents of this report will be considered further in selecting the number and location of stations during a later phase of the hydrometric network review process. Similarly, the reporting capability and format of applied data acquisition and processing systems impacts upon the communications problem and thus must be considered when planning for the dissemination of information to users.

Due to time constraints, it was impossible to discuss all the technical and operational concerns that can exist in designing, maintaining and operating hydrometric networks. Therefore, it was necessary to limit the coverage of the report to a few topics deemed by the authors of importance and relevance to the present network design exercise.

Information on the origins, history and present status of the hydrometric networks in New Brunswick is provided in the following chapter. Technology and operational procedures currently in use are described.

Topics which are primarily technological in nature are discussed in Chapter Three. These are stage measurement technology, velocity and flow measurement technology, and telemetry, as well as the difficult problems of flow measurement during ice cover periods, flow measurement

during breakup, and estuarial flow measurement. Some site-specific considerations are contained in Appendix A.

Topics which are primarily operational are discussed in Chapter Four. These include observers and remote sensing, term stations, frequency of visitation, and transboundary interjurisdictional concerns.

The final chapter contains a visionary lock at future hydrometric networks possible to attain if the recommendations of this report are followed.

2.0 HYDROMETRIC NETWORK IN NEW BRUNSWICK

2.1. HISTORY AND GROWTH

Hydrometric surveys in New Brunswick date back to 1918 when, at the request of the New Brunswick authorities, the Dominion Water Power Branch of the Department of the Interior - Canada extended their Halifax based operations into this province. Data for eighteen regular metering stations in New Brunswick were published in the 1918-19 and 1919-20 Water Resources Paper No. 29 (Smith, K.H. 1921). It is interesting to note that six of these original stations are active today.

Technical staff worked from the district office in Halifax, travelling by train in the early years, and later by automobile. Many of the early stations were established near rail lines for accessibility.

The stream gauging equipment changed very little until the early fifties. At most stations, staff gauges or chain gauges were used to obtain water levels, usually one reading per day. These gauges were read by hired local observers.

In the early 1930's, the continuous water level recorder was first introduced. The new instrument required a stilling well and shelter, but in return produced continuous records from which instantaneous high or low water levels could accurately be determined. The instrument also led to the gradual phasing out of gauge readers. Later, by linking the recorder to the newly developed servo-manometer, initial installation became cheaper as stilling wells were no longer required.

The charts produced by these recorders were computed manually until 1969, when the digitizer and data processing methods were introduced. Records could now be processed much faster.

During 1970, a sub-office was established in Fredericton to facilitate New Brunswick operations. The new office was staffed by six technicians, two supervisors, one clerk and an Area engineer. This move was necessitated by the rapid increase in the number of stream gauging stations during the previous decade (See Figure 2.1).

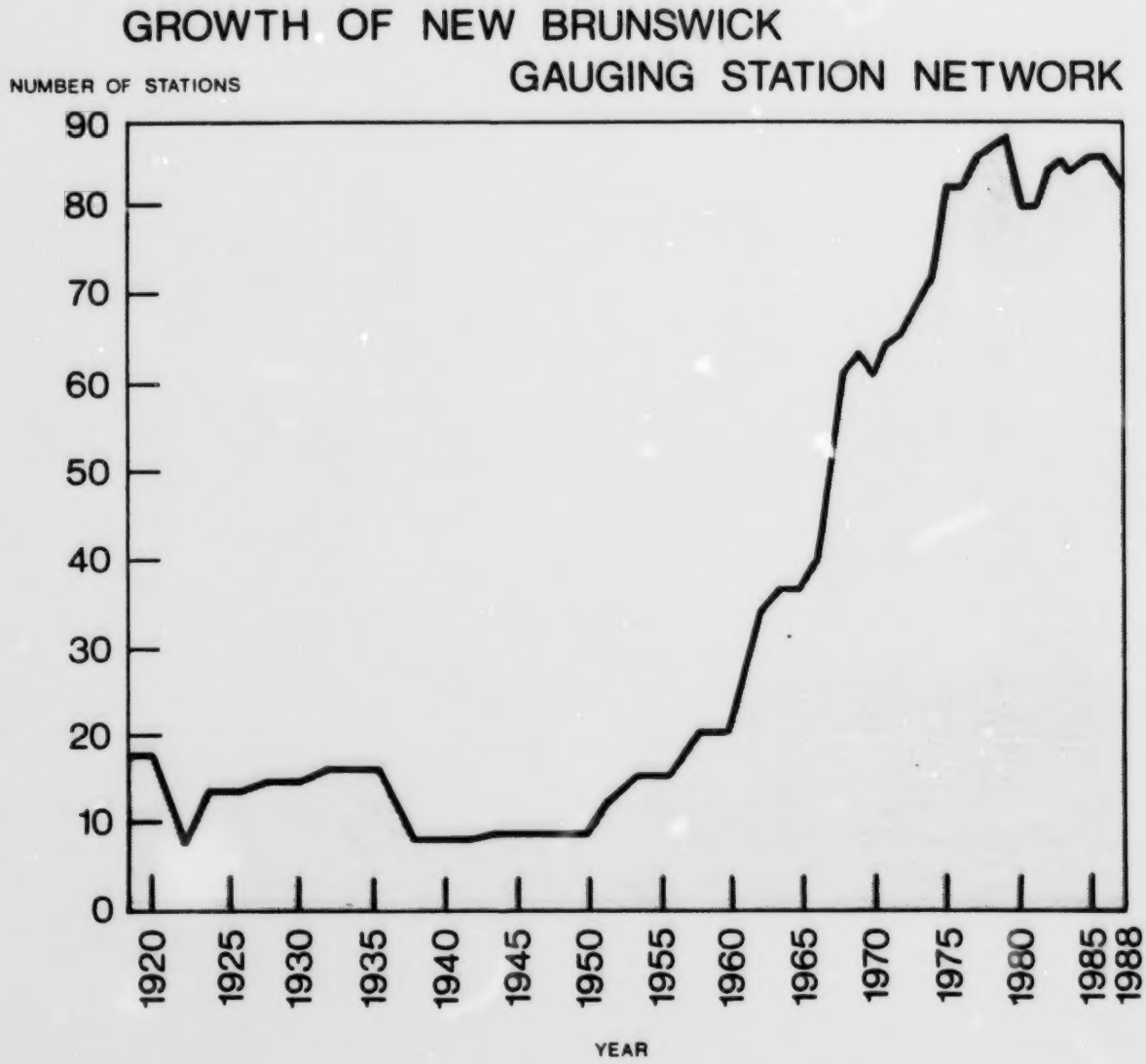

Figure 2.1 Growth of New Brunswick Gauging Station Network

It should be noted that since the establishment of the office, measurements of record high discharge have been obtained at every streamflow gauging site, largely due to closer monitoring of high water events. The move also resulted in much closer ties with New Brunswick data users, such as the New Brunswick Electric Power Commission, the Provincial Water Resource Planning Branch and the University of New Brunswick.

During the seventies, the Fredericton office became involved in other functions in addition to basic stream gauging. The sediment program which began in the late sixties with two stations was expanded to a maximum of six stations. Five groundwater stations were established on the island of Lameque. Technical staff received training in water quality sampling and carried out sampling on a total of fourteen selected stations.

Since the initiation of computerized flood forecasting activities in 1973, Water Survey staff have assisted in operations by providing real-time data during the spring freshet period. This was accomplished by installing and maintaining data telemetry equipment at about forty gauging sites. Additional snow surveys were required to support the forecast work as well as additional discharge measurements on selected streams during the ice period. Data collection platforms (DCPs) for satellite telemetry were installed at remote sites and telemarks at stations where landline communication was readily available.

New techniques, such as the Moving Boat Streamflow Method which improved the potential to measure peak flow in large streams, were introduced.

Figure 2.1 shows another significant increase in the number of gauging stations during the seventies decade. A cooperative agreement between the Water Resources Branch of Environment Canada and the Province of New Brunswick was negotiated in 1975 providing for water quantity surveys to be continued by the Federal Government on a cost-shared basis. This agreement has been renewed annually for the past 12 years.

All instrumentation was converted from Imperial to SI (metric) units in 1979.

2.2 PRESENT STATUS

2.2.1 Instrumentation and Related Surveys

As indicated by Figure 2.1, the number of gauging stations has remained very stable during recent years. Table 2.1 lists the names of all active stations in New Brunswick, as well as the following information: station number, drainage area, regulation, type of data produced, instrumentation including real-time data status, access and control features, electricity, year established, gauge reader status and cost sharing classification.

All stations, with the exception of international stations located in Maine, are equipped with Leopold and Stevens A-35 or A-71 analogue strip chart recorders, coupled to either a float or servo-manometer water level sensor. All stations in New Brunswick are relatively easy to access. Snowmobiles are required to reach some stations during winter; the longest run being approximately a 20 km round trip. A four-wheel drive vehicle and an A.T.C. are used in difficult access situations. All vehicles are equipped with winches and posi-traction rear axles.

Equipment and techniques used to measure discharge have not changed appreciably since 1918. Open water measurements are obtained through the use of a Price current meter by wading, or from a boat, cableway or bridge. Approximately three measurements per year are obtained through the ice cover.

Table 2.2 identifies stations where data on other parameters are obtained including water quality, sediment, snow, ice thickness and climate.

It is interesting to note that although the number of stations has increased since 1970 and additional responsibilities have been assumed, the staff has been reduced by two person years. Present staff consists of 5 technicians, 1 supervisor, 1 clerk and an Area Head. The clerical position will be discontinued effective May 1988.

TABLE 2.1 ACTIVE HYDROMETRIC STATIONS IN NEW BRUNSWICK

STATION NUMBER	STATION NAME	YEAR ESTAB.	COST SHARING CLASSIF.	INSTRUMENT-ATION	TYPE OF DATA	CONTROL	ACCESS	METHOD OF MEASUREMENT	D.A. km_2	REGULATED	GAUGE OBSERVER	ELECTRICITY
01AD002	Saint John R. at Fort Kent	1926	F-3	Punch, Float	Q	5	2	Ice, Bridge	14700	No	No	Yes
01AD003	St. Francis R.	1951	F-3	A-35, Float	Q	1	3	Wading, Cableway, No B.W.	1350	No	No	No
01AD004	Saint John R. at Edmundston	1967	F-3	A-35, Manometer	W.L.	N.A.	1	N.A.	15500	No	No	Yes
01AE001	Fish R. at Fort Kent	1903	F-3	Punch, Float	Q	3	1	Wading, Cableway	2260	No	No	Yes
01AF002	Saint John R. at Grand Falls	1930	F-3	A-35, Manometer	Q	3	2	Cableway, No B.W.	21900	Yes	No	Yes
01AF003	Green R.	1962	F-2	A-35, Float	Q	5	1	Ice, Wading, Bridge	1150	Yes	No	Yes
01AF007	Grande Riviere	1976	F-P-3	A-35, Manometer	Q	5	1	Ice, Wading, Bridge	339	No	No	No
01AG002	Limestone Stream	1967	F-3	A-35, Float	Q	7	2	Ice, Wading, Cableway	199	No	No	Yes
01AG003	Aroostook R.	1974	F-3	A-35, Manometer	Q	3	3	Wading,Cableway, No. B.W.	6060	Yes	No	Yes
01AH002	Tobique R. at Riley Brook	1954	F-2	A-35, Float	Q	5	1	Ice, Wading, Bridge	2230	Yes	No	Yes
01AH003	Tobique R. at Plaster Rock	1954	F-2	A-35, Float	Q	5	1	Ice, Wading Bridge	3130	Yes	No	Yes
01AH004	Tobique R. at Narrows	1953	Other	-	Q	-	-	Plant releases	4330	Yes	-	-
01AH005	Mamozekel R.	1972	F-P-3	A-35, Float	Q	5	3	Ice, Wading Bridge	230	No	No	No
01AJ001	Saint John R. at Florenceville	1951	F-4	A-35, Manometer	Q	4	1	Moving Boat, Boat, No B.W.	34200	Yes	No	Yes
01AJ003	Meduxnekeag R.	1967	F-3	A-35, Float	Q	5	2	Ice, Wading Cableway	1210	No	Yes	Yes
01AJ004	Big Presque Isle Str.	1967	F-3	A-35, Float	Q	5	2	Ice, Wading Cableway	484	Yes	Yes	Yes
01AJ008	Saint John R. at Hartland	1973	F-P-2	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Yes	No	Yes
01AJ009	Saint John R. at Simonds	1974	F-1	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Yes	No	No
01AJ010	Becaguimec Stream	1973	F-P-3	A-35, Float	Q	5	1	Wading, Bridge No B.W.	350	No	No	Yes

continued..

TABLE 2.1 CONTINUED:-

STATION NUMBER	STATION NAME	YEAR ESTAB.	COST SHARING CLASSIF.	INSTRUMENT-ATION	TYPE OF DATA	CONTROL	ACCESS	METHOD OF MEASUREMENT	D.A. km_2	REGULATED	GAUGE OBSERVER	ELECTRICITY
01AJ011	Cold Stream	1973	F-P-3	A-35, Float	Q	10	1	Wading, Bridge, No B.W.	156	No	Yes	Yes
01AK001	Shogomoc Stream	1918	F-P-3	A-35, Float	Q	3	4	Ice, Wading, Cableway	234	No	No	No
01AK003	Saint John R. at Fredericton	1960	F-4	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Yes	No	Yes
01AK004	Saint John R. below Mactaquac	1961	F-4	A-35, Manometer	Q	7	1	Moving boat, Conventional boat-	39900	Yes	No	Yes
01AK005	Mid. Br. Nashwaaksis Str. at Royal Road	1965	F-P-3	A-35, Float	Q	7	1	Wading, Bridge, No B.W.	26.9	No	No	Yes
01AK006	Mid. Br. Nashwaaksis Str. at Sandwith's Farm	1966	F-P-3	A-35, Float	Q	4	1	Wading, No B.W.	5.70	No	No	Yes
01AK007	Nackawic Stream	1967	F-P-3	A-35, Manometer	Q	7	1	Ice, Wading, Bridge	240	No	No	Yes
01AK008	Eel R. at Scott Siding	1974	F-P-3	A-35, Float	Q	5	5	Ice, Wading, Cableway	531	No	No	Yes
01AK009	Saint John R. at Mactaquac Gen. Stn.	1980	F-P-2	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Yes	No	Yes
01AL002	Nashwaak R. at Durham Bridge	1961	F-P-3	A-35, Float	Q	4	1	Ice, Wading, Bridge	1450	No	No	Yes
01AL003	Hayden Brook	1970	F-1	A-35, Manometer	Q	7	3	Wading, No winter m.m.	6.48	No	No	No
01AL004	Narrows Mountain Brook	1972	F-1	A-35, Manometer	Q	7	2	Wading, No winter m.m.	3.89	No	No	No
01AL006	Nashwaak R. at Stanley	1982	F-2	A-35, Manometer	Q	5	1	Ice, Wading, Bridge	641	No	No	Yes
01AN001	N. Br. Oromocto R.	1962	F-P-3	A-35, Float	Q	5	1	Ice, Wading, Bridge	557	No	No	Yes
01AN001	Castaway Stream	1972	F-P-3	A-35, Float	Q	7	1	Ice, Wading, Bridge	34.4	No	No	Yes
01AN002	Salmon R. at Castaway	1974	F-P-3	A-35, Manometer	Q & P	5	3	Ice, Wading, Boat	1050	No	No	No
01AQ002	Saint John R. at Maugerville	1965	F-2	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Yes	No	Yes

continued..

TABLE 2.1 CONTINUED:-

STATION NUMBER	STATION NAME	YEAR ESTAB.	COST SHARING CLASSIF.	INSTRUMENT-ATION	TYPE OF DATA	CONTROL	ACCESS	METHOD OF MEASUREMENT	D.A. km_2	REGULATED	GAUGE OBSERVER	ELECTRICITY
01AB003	Grand Lake	1965	P-2	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	No	Yes	Yes
01AB004	Jemseg R.	1966	P-1	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Yes	No	Yes
01AB009	Burpee Millstream	1976	P-P-3	A-35, Manometer	Q	7	3	Ice, Wading, Cable follower	93.2	No	No	No
01AB010	French Lake	1980	P-2	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	No	No	No
01AP002	Canaan R.	1925	P-P-3	A-35, Float	Q	5	1	Ice, Wading, Bridge	668	No	No	Yes
01AP003	Saint John R. at Oak Point	1923	P-1	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Yes	No	Yes
01AP004	Kennebecasis R.	1961	P-P-3	A-35, Manometer	Q	4	1	Ice, Wading, Bridge	1100	No	Yes	Yes
01AP005	Saint John R. at Saint John	1966	P-1	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Tidal	No	Yes
01AP006	Nerepis R.	1976	P-P-3	A-35, Float	Q	5	3	Ice, Wading, Cableway	293	No	No	No
01AQ001	Lepreau R.	1916	P-4	A-35, Float	Q	5	1	Ice, Wading, Cableway	239	No	No	Yes
01AQ002	Magaguadavic R.	1917	P-4	A-35, Manometer	Q	3	2	Ice, Wading, Cableway	1420	Yes	No	No
01AQ007	Magaguadavic Lake	1978	P-2	A-35, Manometer	W.L.	N.A.	3		N.A.	No	No	Yes
01AQ008	Piskahegan Stream	1982	P-P	A-35, Manometer	Q	3	2	Ice, Wading, Cableway	197	No	No	No
01AQ009	Lake Utopia	1985	P-2	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Yes	No	No
01AR004	St. Croix R. at Vanceboro	1928	P-3	Punch, Manometer	Q	3	1	Wading, Cable-way, No. B.W.	1080	Yes	No	Yes
01AR005	St. Croix R. at Baring	1959	P-3	Punch, Float	Q	3	1	Cableway, No B.W.	3550	Yes	No	Yes
01AR006	Dennis Stream	1966	P-4	A-35, Float	Q	5	1	Ice, Wading, Bridge	115	No	No	Yes
01AR009	Grand Lake at Forest City	1969	P-3	A-35, Float	W.L.	N.A.	1	N.A.	N.A.	Yes	Yes	Yes
01AR010	Spednic Lake	1967	P-3	A-35, Float	W.L.	N.A.	1	N.A.	N.A.	Yes	Yes	Yes
01AR011	Forest City Stream	1969	P-3	A-35, Float	Q	5	2	Wading, Cableway, No B.W.	357	Yes	Yes	Yes

continued..

TABLE 2.1 CONTINUED:-

STATION NUMBER	STATION NAME	YEAR ESTAB.	COST SHARING CLASSIF.	INSTRUMENT-ATION	TYPE OF DATA	CONTROL	ACCESS	METHOD OF MEASUREMENT	D.A. km_2	REGULATED	GAUGE OBSERVER	ELECTRICITY
01AR012	Chemcook Stream	1966	F-P-2	A-35, Float	Q	5	2	Wading, No B.W.	N.A.	No	No	Yes
01AR013	Grand Falls Flowage	1960	F-3	A-35, Float	W.L.	N.A.	1	N.A.	N.A.	Yes	No	Yes
01BC001	Restigouche R. at Kedgwick	1962	F-2	A-35, Float	Q	3	2	Ice, Wading, Boat	3160	No	No	No
01BE001	Upsalquitch R.	1918	F-4	A-35, Float	Q	3	1	Ice, Wading, Bridge	2270	No	Yes	No
01BJ001	Tetagouche R.	1923	F-4	A-35, Manometer	Q	4	4	Ice, Wading, Bridge	363	No	No	No
01BJ003	Jacquet R.	1964	F-4	A-35, Float	Q	5	4	Ice, Wading, Bridge	510	No	No	No
01BJ007	Restigouche R. at Raft. Grd. Brk.	1968	F-4	A-35, Manometer	Q	3	1	Ice, Boat (2 technicians)	7740	No	No	Yes
01BJ009	Walker Brook	1980	P-2	A-35, Float	Q	5	1	Ice, Wading, Cableway	60.8	Yes	No	No
01BJ011	Nigadoo R.	1981	P 2	A-35, Manometer	Q	5	3	Ice, Wading, Cableway	123	No	No	No
01BJ012	Eel R. at Dundee	1983	F-P-3	A-35, Manometer	Q	5	2	Ice, Wading, Bridge	43.2	No	No	No
01BK003	Nepisiquit R.	1921	Other	-	Q	-	-	Plant releases	1840	Yes	-	-
01BK006	Forty Mile Brook	1981	F-P-3	A-35, Manometer	Q	6	5	Wading, Bridge No B.W.	13.0	No	No	No
01BJ010	Middle R.	1981	P-2	A-35, Manometer	Q	5	1	Ice, Wading, Cableway	190	No	No	No
01BL001	Bass R.	1965	F-4	A-35, Float	Q	6	3	Ice, Wading, Bridge	175	No	No	No
01BL002	Riviere Caraquet	1969	F-4	A-35, FLoat	Q	5	2	Ice, Wading, Bridge	173	No	No	No
01BL003	Big Tracadie R.	1970	F-4	A-35, Float	Q	5	5	Ice, Wading, Cableway	383	No	No	No
01BQ001	S.W. Miramichi R.	1918	F-4	A-35, Manometer	Q	3	1	Ice, Wading, Bridge	5050	No	No	Yes
01BQ003	Barnaby R.	1973	F-P-3	A-35, Float	Q	5	4	Ice, Wading, Cableway	484	No	No	No

continued..

TABLE 2.1 CONCLUDED:-

STATION NUMBER	STATION NAME	YEAR ESTAB.	COST SHARING CLASSIF.	INSTRUMENT-ATION	TYPE OF DATA	CONTROL	ACCESS	METHOD OF MEASUREMENT	D.A. km_2	REGULATED	GAUGE OBSERVER	ELECTRICITY
01BG002	Ranoue R.	1965	F-P-3	A-35, Float	Q	5	2	Ice, Wading, Cableway	611	No	No	Yes
01BG004	Bartibog R.	1978	F-P-3	A-35, Float	Q	5	3	Ice, Wading, Cableway	316	No	No	No
01BF001	L.S.W. Miramichi R.	1951	F-P-3	A-35, Manometer	Q	5	1	Ice, Wading, Bridge	1340	No	No	No
01BQ001	N.W. Miramichi R.	1961	F-P-3	A-35, Float	Q	4	1	Ice, Wading, Cableway	948	No	No	Yes
01BR001	Kouchibouguac R.	1930-33 1969	F-4	A-35, Float	Q	4	1	Ice, Wading, Bridge	177	No	Yes	Yes
01BS001	Coal Branch R.	1964	F-4	A-35, Float	Q	5	1	Ice, Wading, Bridge	166	No	No	No
01BT001	Kinnear R.	1985	F-P-3	A-35, Float	Q	6	1	Ice, Wading, Bridge	32.1	No	No	No
01BU002	Petitcodiac R.	1961	F-4	A-35, Float	Q	7	1	Ice, Wading, Bridge	391	No	No	No
01BU003	Turtle Creek	1962	F-2	A-35, Float	Q	6	1	Ice, Wading, Bridge	129	No	Yes	Yes
01BV006	Point Wolfe R.	1964	F-1	A-35, Manometer	Q	6	4	Wading, Cableway, Ice	130	No	No	No

Cost-sharing codes:

F is federal; P is provincial
- F-1: federal departmental programs
- F-2: interprovincial waters
- F-3: international waters
- F-4: national water quantity inventory
- F-5: specific purpose monitoring
- F-P-2: river basin management
- F-P-3: water quantity inventory

Type of Data:

- Q - streamflow
- W.L.- water level only

Control:

The number represents the average number of discharge measurements required to verify control. The scale is from 1 to 10 with one being excellent, five - good, and ten - poor.

Access:

The scale is from 1 to 5:

1 - excellent
2 - very good
3 - good
4 - fair
5 - difficult and expensive

TABLE 2.2 HYDROMETRIC STATIONS WHERE DATA ON OTHER PARAMETERS ARE OBTAINED

STATION NUMBER	STATION NAME	TYPE OF DATA	REAL TIME	W.Q. OVERVIEW	W.Q. LRTAP	SED.	SNOW SURVEYS	ICE THICKNESS	CLIMATE
01AD002	Saint John R. at Fort Kent	Q	D.C.P. & Tel.					X	
01AD003	St. Francis R.	Q	D.C.P.				X		
01AD004	Saint John R. at Edmundston	W.L.	Tel.						
01AE001	Fish R. at Fort Kent	Q	Tel.						
01AF002	Saint John R. at Grand Falls	Q	Tel.	X					
01AF003	Green R.	Q	Tel.						
01AF007	Grande Riviere	Q	D.C.P.			X		X	
01AG002	Limestone R.	Q	Tel.						
01AG003	Aroostook R.	Q	Tel.						
01AH002	Tobique R. at Riley Brook	Q	Tel.				X	X	
01AH003	Tobique R. at Plaster Rock	Q	Tel.					X	
01AH005	Mamozekel R.	Q	D.C.P.						
01AJ001	Saint John R. at Florenceville	Q	Tel.						
01AJ003	Meduxnekeag R.	Q	Tel.	X				X	
01AJ004	Big Presque Isle Stream	Q	Tel.					X	

continued..

TABLE 2.2 CONTINUED:-

STATION NUMBER	STATION NAME	TYPE OF DATA	REAL TIME	W.Q. OVERVIEW	W.Q. LRTAP	SED.	SNOW SURVEYS	ICE THICKNESS	CLIMATE
01AJ008	Saint John R. at Hartland	W.L.	Tel.						
01AJ009	Saint John R. at Simonds	W.L.	Tel.						
01AJ010	Becaguimec Stream	Q	Tel.					X	
01AJ011	Cold Stream	Q	Tel.					X	
01AK001	Shogomoc Stream	Q	D.C.P.						
01AK003	Saint John R. at Fredericton	W.L.	Tel.						
01AK004	Saint John R. below Mactaquac	Q	Tel.						
01AK007	Nackawic Stream	Q	Tel.					X	
01AK008	Eel R. at Scott Siding	Q	Tel.					X	
01AK009	Saint John R. at Mactaquac Gen. Stn.	W.L.	Tel.						
01AL002	Nashwaak R. at Durham Bridge	Q	Tel.				X	X	
01AL004	Narrows Mountain Brook	Q				X			
01AL008	Nashwaak R. at Stanley	Q	Tel.					X	
01AM001	N. Branch Oromocto R.	Q	Tel.		X		X	X	
01AN002	Salmon R. at Castaway	Q	D.C.P.		X		X	X	X

continued..

TABLE 2.2 CONTINUED:-

STATION NUMBER	STATION NAME	TYPE OF DATA	REAL TIME	W.Q. OVERVIEW	W.Q. LRTAP	SED.	SNOW SURVEYS	ICE THICKNESS	CLIMATE
01A0002	Saint John R. at Maugerville	W.L.	Tel.						
01A0003	Grand Lake	W.L.	Tel.						
01A0004	Jemseg R.	W.L.	Tel.						
01A0010	French Lake	W.L.	Tel.						
01AP002	Canaan R.	Q	Tel.						
01AP003	Saint John R. at Oak Point	W.L.	Tel.						
01AP004	Kennebecasis R.	Q	Tel.	X		X	X	X	
01AP005	Saint John R. at Saint John	W.L.	Tel.						
01AP006	Nerepis R.	Q					X		
01AQ001	Lepreau R.	Q	Tel.		X				
01AQ008	Piskahegan Stream	Q	D.C.P.						
01AR005	St. Croix R. at Baring	Q	Tel.	Milltown X					
01AR006	Dennis Stream	Q	D.C.P.			X			
01BC001	Restigouche R. at Kedgwick	Q						X	
01BE001	Upsalquitch R.	Q	D.C.P.						
01BJ007	Restigouche R. at Rafting Grd. Brook	Q	D.C.P.	X			X	X	X

continued..

TABLE 2.2 CONCLUDED:-

STATION NUMBER	STATION NAME	TYPE OF DATA	REAL TIME	W.Q. OVERVIEW	W.Q. LRTAP	SED.	SNOW SURVEYS	ICE THICKNESS	CLIMATE
01BJ009	Walker Brook	Q							
01BK003	Nepisiquit R.	Q		X				X	X
01BL003	Big Tracadie R.	Q	D.C.P.						
01BQ001	S.W. Miramichi R.	Q	Tel.	X		X		X	
01BQ001	N.W. Miramichi R.	Q	D.C.P.	X					
01BS001	Coal Branch R.	Q				X			
01BU002	Petitcodiac R.	Q		X				X	
01BV006	Point Wolfe R.	Q	D.C.P.		X		X(2)		

Symbol and abbreviations:

Type of data: Q - discharge; W.L. - water level
Tel.: telemarks
D.C.P.: data collection platform

2.2.2 Data Use

Reasons for establishment of stream gauging stations in New Brunswick are varied and in some cases undocumented. Some of the principal agencies requesting data are as follows: the Saint John River Forecast Centre, municipalities, the Department of Fisheries and Oceans, the New Brunswick Electric Power Commission and universities in the province.

Some stations initiated for a specific purpose with a definite project time frame obtained a broader user base and thus continue to be operated after the initiator stopped supporting the station. Often, the cost-sharing classification may change at that time. In the past, when dictated by financial considerations, stations were discontinued using existing network reviews as criteria. Some stations have been moved from one stream to another (within the same hydrologic region) because of poor initial site selection.

2.2.3 Data Generating Procedures

Present data generating procedures are illustrated by Figure 2.2. After documentation, charts are forwarded by mail to the Dartmouth office for processing. Printouts of the data are normally returned via mail, although with the introduction of a computer terminal and printer in the Fredericton office in 1985, data can be obtained much faster if necessary.

Corrections and new stage discharge tables are entered via the terminal. With the terminal and printer, daily water levels and discharges, or hourly discharges are readily retrievable from Dartmouth.

2.3 QUALITY CONTROL

2.3.1 Quality Assurance Program

Regardless of the technology and operational procedures employed, there is a need to have a system in place to maintain acceptable standards so that users can use hydrometric data in design and operational applications with a reasonable degree of confidence. This was recognized during the Water Survey of Canada Technical Committee meeting held at Water Resources Branch headquarters in Ottawa in October, 1984, from which the

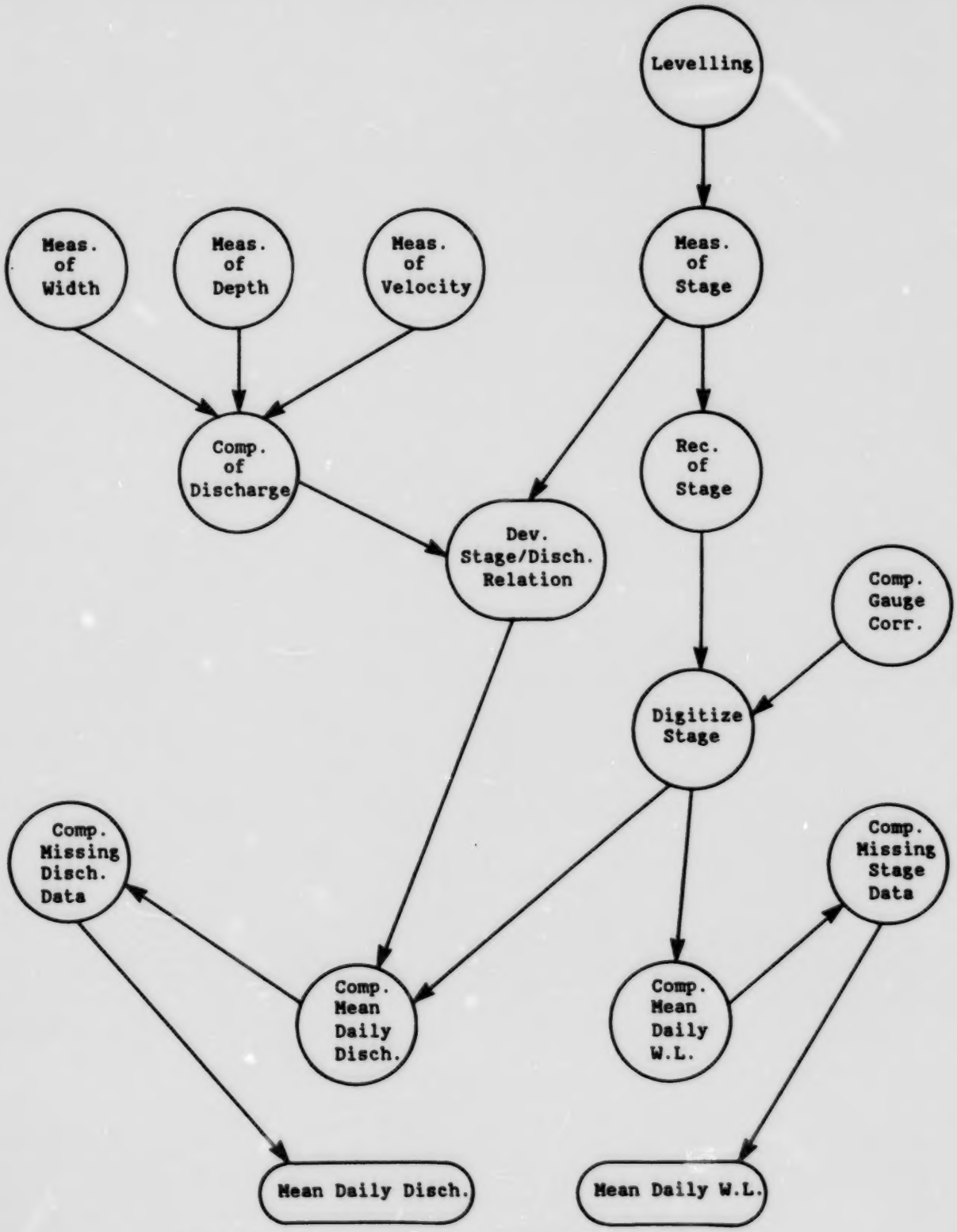

Figure 2.2 Hydrometric Data Generating Activities

following statement emanated: "It has been pointed out on several occasions that there is a need for Water Resources Branch not only to ensure our data is of sufficient quality, but also to demonstrate that we have a system in place that will give management and data users that assurance". The Quality Assurance Program for the Atlantic Region has been developed and implemented over the past two years. Technicians, supervisors and Area Heads/Area Engineers check the quality of the data prior to publication.

Management audits the procedures to ensure that data are produced using standards as defined by the field and office procedural manuals, collectively known as the National Standards.

Figure 2.3 illustrates the implementation and monitoring procedures carried out in the Quality Assurance Program.

2.3.2 Quality Index

A system has been developed in the Atlantic Region to define the quality of the data produced from a gauging station for a particular year. The method is based on the following criteria:

1. discharge measurement scatter and measurement voids on the stage-discharge rating curve;
2. number of days of missing record;
3. number of days affected by backwater conditions;
4. frequency of winter measurements; and
5. periods of record when shifts must be applied to the rating curve.

The technique (described in Appendix B) provides a numerical index of the quality of the data produced for each gauging station. The final value obtained for a station is used to do relative comparisons and to identify stations whose output could be improved.

Shortcomings in data collection (eg. record loss) can be identified by this index and technological and operational improvements made as necessary.

2.3.3 Station Work Plans

Another innovation of the Atlantic Region of the Water Resources Branch, Inland Waters/Lands, Environment

QUALITY ASSURANCE PROGRAM
WATER RESOURCES BRANCH
ENVIRONMENT CANADA

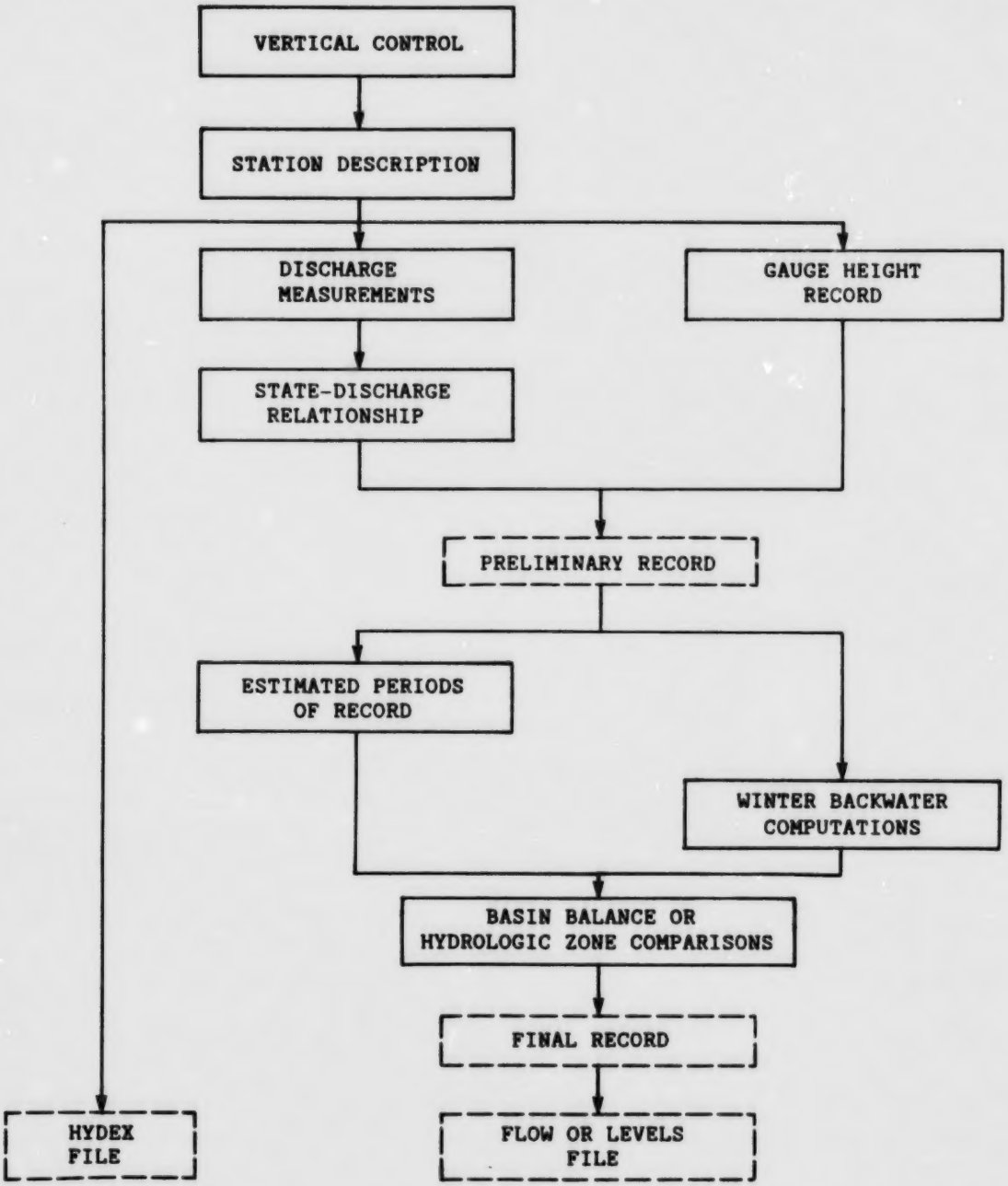

Figure 2.3 Quality Assurance Program - Water Resources Branch

Canada, is the introduction of the individual station work plans (Figure 2.4). These work plans define operational requirements on an annual basis. At the beginning of each calendar year, the technician and supervisor establish goals for each station. These goals include the desired number of discharge measurements within specified stage ranges, station checks, timing and frequency of related surveys and time frames for various stages of computations. At the end of the year, a report is produced for each station indicating whether or not goals were achieved, and if not, why.

The introduction of Station Work Plans and Quality Indices are meant to improve the overall quality of published data.

2.3.4 Training

The accuracy, consistency and timeliness of data is dependent upon a well-trained staff. This is becoming increasingly important as rapidly evolving technology is being applied in the operational hydrometric network. The rate of application of such technology is to some extent dependent upon the data collection agency's capability to train its staff. Unless staff are properly trained, serious operational difficulties will likely arise.

Training modules are presently being developed to provide uniform instructions to technical staff on all phases of office and field work. These training modules will be formally presented to all technical staff during various levels in their career development. This will lead to uniformity in training across Canada.

Training modules will be developed for the operation and maintenance of new equipment as required and will become part of the training program.

STATION WORK PLAN

STATION: _____

TECHNICIAN: _____

FIELD PROGRAM FOR 19

	PROGRAM GOALS	TOTAL TO DEC 31	REMARKS
HYDROMETRIC SURVEY			
Total Visits			
Discharge MM			
Open Water			
Winter			
Water Level Checks			
Real-Time Equip. Chk.			
Annual Inspections			
Cableway Inspections			
SEDIMENT SURVEY			
Observer Samples			
Automatic Samples			
Technician Samples			
WATER QUALITY SURVEY			
Overview Surveys			
LRTAP Surveys			
Radionuclide Surveys			
GROUNDWATER SURVEY			
Visits			
Level Checks			
SNOW SURVEY			
ICE SURVEY			

MAINTENANCE:

Proposed (Describe)	Major ( )	Completed

OPEN WATER MEASUREMENT PROGRAM FOR 19__

PROPOSED PROGRAM	NO. OF MM GOAL	NO. OF MM ACTUAL	MODIFIED PROGRAM	NO. OF MM GOAL	NO. OF MM ACTUAL
From ____m & above			From ____m & above		
From ____ to ____m			From ____ to ____m		
From ____ to ____m			From ____ to ____m		
From ____ to ____m			From ____ to ____m		
From ____m & below			From ____m & below		

ANALYSIS FOR 19__

OPEN WATER MM

NUMBER OF MM	Recorded Stage	Max ___m Min ___m	
	Occurrence of Goals*		
	Obtained Goals		
	Obtained/Occurred	____%	"x" if =>80% ☐
VERTICALS	MM with width >4m		
	MM with vertical =>20		
	MM to Standard	____%	"x" if 100% ☐
MAXIMA	Recorded Max Q	____m3/s	
	Max Q measured	____m3/s	
	Measured/Recorded	____%	"x" if =>80% ☐
MINIMA	Recorded Min Q	____m3/s	
	Min Q measured	____m3/s	
	Recorded/Measured	____%	"x" if =>80% ☐
HISTORIC	Historic Max MM	____m3/s	"x" if exceeded ☐
	Historic Min MM	____m3/s	"x" if exceeded ☐
ANNUAL LEVELLING	No. of BM levelled	____	"x" if =>3 ☐
	Closure	____m	"x" if <0.003 ☐
LOST CHART RECORD	Days	____	"x" if =<10 ☐

HYDROMETRIC COMPUTATIONS FOR 19__

	CHART PROCESS	GAUGE CORR.	S-D RELATIONS	% PERIODS	BACKWATER JAN-APR	BACKWATER NOV-DEC	R.O. ANALYSIS	APPR'D PUBL.
GOAL (date)								
COMPLETED (date)								
MET GOAL ("x")								

SEDIMENT COMPUTATIONS FOR 19__

	CONC ON CHART	CHART PROCESS	SED-CON UPDATE	TEMP CODED	APPR'D. PUBL.
GOAL (date)					
COMPLETED (date)					
MET GOAL ("x")					

* Without regard to budget and overtime restraints, darkness and station priority.

Figure 2.4 Station Work Plan

3.0 TECHNOLOGY ISSUES

3.1 SCOPE

Topics which are primarily technological in nature are discussed in this chapter. These are stage measurement technology, velocity and flow measurement technology, telemetry, as well as the difficult problems of flow measurement during ice cover periods, flow determination during breakup, and estuarial flow measurement.

3.2 STAGE MEASUREMENT TECHNOLOGY

3.2.1 General

The measurement and recording of stage are important, as the stage record provides the means by which daily discharge calculations are made. In addition, some gauging stations are operated exclusively for the collection of stage data for such purposes as navigation and computation of reservoir contents (Inland Waters Directorate, 1983).

The World Meteorological Organization produced a catalogue of water level recorders. It contains descriptions of 33 water level recorders that have been manufactured and proven reliable in 10 member countries. Float-actuated and pressure-actuated devices are included, as are some ultrasonic devices (World Meteorological Organization, 1983).

In Canada, there is an evaluation being done to assess water level sensors that have characteristics compatible with data telemetry systems. In addition, the Water Resources Branch of Environment Canada is reviewing devices that would replace currently operational water level sensors which use materials that over long periods of continual exposure might be harmful to human health. New devices are expected to be placed in operation during the next few years.

In New Brunswick, there is a need for improvements in stage measurement and data delivery technology for such critical operations as flood forecasting. For example, servo-manometer pressure-actuated devices in general require more maintenance to ensure proper operation. Even with proper maintenance, malfunctions such as leaks in the gas purge system can cause undetected

errors which will result in erroneous data being input into models (eg. DWOPER and ESTUAR). In addition, the complexity can be reduced and the reliability increased by the installation of stage sensors specifically designed to be used with telemetry devices. When more accurate and reliable instrumentation becomes available, improvements should be made in station instrumentation.

3.2.2 Manual Water Level Instrumentation

A manual gauge is a non-recording gauge used to obtain gauge heights and can be operated either independently or as a reference gauge for a water level recorder (Inland Waters Directorate, 1983). Types of manual water level gauges include:

1. vertical (staff);
2. inclined;
3. wire weight;
4. hook;
5. electric tape (contact);
6. float; and
7. crest.

The advantages and disadvantages of manual water level instrumentation are as follows:

Advantages

- inexpensive
- reasonably reliable
- easily repaired because of low complexity
- easily installed
- low training requirements
- accurate
- portable, reuseable
- low cost checking of continuous recorders

Disadvantages

- point values obtained in space and time may miss extreme events unless especially designed and situated for that purpose (eg. crest gauge)
- low frequency of observation
- requires person at site
- measurements may be missed due to sickness, vacation, etc.

- measurements subject to human error in reading and recording; quality checks required
- not compatible with current data handling procedures
- applicable only to periods of open water or ice-free conditions
- usually only daylight application
- safety problems may exist for observers
- may be subject to vandalism due to location

3.2.3 Float-Actuated Devices; Continuous Recorders

All float-actuated instruments operate on the principle that a float will rest on the water surface and rise and fall as the water level changes, thus moving a wire or tape or other connector coupled to a recording mechanism (Inland Waters Directorate, 1983).

The advantages and disadvantages of float-actuated devices are as follows:

Advantages

- continuous record can be obtained
- accurate under all weather conditions
- reasonably reliable (low complexity)
- easily repaired; parts readily available
- easily installed
- moderate training requirement
- cost competitive with other conventional continuous recording devices; but more expensive than manual gauges
- zero power requirements
- interfacing with telemetry possible
- infrequent site visits required
- chart record may be useful for studying backwater (depending upon frequency of chart retrieval)

Disadvantages

- ground conditions must be suitable for constructing stilling well
- safeguards (heat source or chemicals) needed against freezing of stilling well
- location nearer to watercourse needed due to the costs of constructing the stilling well, thus making it more susceptible to destruction by ice or water
- intake may be blocked

- lost period of record may result if malfunction not detected until site visit
- stilling well construction may cause sedimentation of watercourse or other problems of concern to fisheries agencies and environmentalists
- safety problems may exist if station improperly maintained or if well not properly covered
- bulky
- parts expensive
- record requires digitization in order to be compatible with electronic data handling procedures.

In Canada, the float-actuated recorders used are the Stevens Type A-35 or A-71 recorders.

3.2.4 Conventional (Servo-Manometer) Pressure-Actuated Devices; Continuous Recorders

Pressure-actuated devices are generally used when construction and operation of a stilling well would be costly and difficult, such as along streams with high or rocky banks necessitating blasting, or with eroding or fluvial channels (Inland Waters Directorate, 1983).

The advantages and disadvantages of pressure-actuated devices are as follows:

Advantages

- continuous record
- can be used at almost any location regardless of ground conditions or channel geometry
- site installation can be done faster than putting in stilling wells
- no costly items in stream channel (i.e. parts in contact with water can be easily and cheaply replaced)
- interfacing with telemetry equipment possible
- chart records can be used in studying backwater and ice breakup

Disadvantages

- prone to malfunction
- fittings may leak due to changing temperature
- higher maintenance and repair costs
- parts expensive
- greatest use of power (i.e. battery or AC)

- difficult to diagnose problems; high level of training required
- nitrogen source required; difficult and dangerous to transport making use at remote sites impractical
- environmentally unacceptable due to mercury use
- safety and health problems for staff due to the transport and use of nitrogen and mercury
- high initial cost
- accuracy affected by temperature, density, length of pressure line, and stability of housing
- orifice line subject to silting, moving, and freezing; requires protection
- orifice line must be carefully placed sloping downward
- accuracy affected by changes in velocity
- records are bulky and have to be digitized in order to be compatible with electronic data handling procedures
- power source required for heating purposes.

3.2.5 Electronic Systems with Pressure or Ultrasonic Sensors

Electronic pressure and ultrasonic sensors are being evaluated for use with electronic data acquisition and telemetry systems.

Pressure sensors convert static water pressure (head) to an analogue voltage signal which is converted to digital values by an analogue to digital converter in the data acquisition system. Pressure transducers can be used in either a submerged installation or in-line with a gas purge system.

An ultrasonic sensor emits pulses at a known frequency. The inaudible sound waves are reflected by the liquid-air interface and received by the sensor. The round-trip time in either air or water, i.e. the time elapsed in transmitting and receiving the echo, is electronically measured as an output signal proportional to the height of the column of water or air measured, which is then converted to water level.

The advantages and disadvantages of electronic water level systems are as follows:

Advantages

- compatible with electronic data processing and telemetry equipment

- data collection automation possible
- very easy to install
- easy to replace
- easy to transport to and from a site
- site visitation could be reduced to maintenance visits with proper telemetry devices
- more reliable than conventional instrumentation
- equivalent in cost to lowest priced conventional instrumentation
- no environmental contamination
- need for nitrogen may be eliminated by submergence
- lower power requirements than for servo-manometers

Disadvantages

- temperature sensitive: must be compensated for temperature; a signal transformation is required
- record cannot be examined at site in conventional sense
- limited operational experience in hydrometric applications
- training regarding instrumentation and concept of electronic data acquisition and processing needed
- takes discrete samples but frequency of data acquisition can be adjusted.

Electronic systems are considered internationally as the next generation of stage technology instrumentation. Several different electronic devices in use are described in the aforementioned catalogue of water level sensors.

3.2.6 Comments on Cost and Accuracy

Manual gauges are the least expensive. If installed properly, they are also the most accurate. However, overall accuracy is decreased by the low sampling rates. There are operational and administrative costs associated with the hiring of observers. These costs are expected to rise with increases in salary and expenses.

Conventional float or servo-manometer pressure systems cost virtually the same in instrumentation and installation. Float-actuated systems measure stage to the same level of accuracy as manual gauges, but have the additional advantage of continuous recording and are considered an order of magnitude better in accuracy

than servo-manometer pressure systems. Furthermore, servo-manometers use mercury as a pressure sensing liquid. Mercury is considered a hazard to human health in high concentrations or over long exposure periods.

Electronic water level sensors are not expected to increase in price because manufacturing costs are generally decreasing and thus are expected to remain less expensive than conventional servo-manometer or stilling well/float water level stations. (Please refer to the Table 3.1.) Electronic instrumentation will be more reliable and provide greater warning of failure. Thus lost record will be reduced. If the sensitivity of the model is in the same order of magnitude as the sensitivity of the measuring instrument, this will lead to smaller modelling errors.

3.2.7 Recommendations

(1) Conventional pressure-actuated devices (servo-manometers) should no longer be purchased. Strong consideration should be given to the installation of electronic systems at new stations. This will reduce initial capital expenditures and complexity of instrumentation. Accuracy should be increased due to a decrease in loss of record.

(2) A strategy for replacing already installed conventional pressure-actuated devices (servo-manometers) with electronic systems should be developed and implemented. A budget and work plan for replacing servo-manometers should be part of this strategy.

(3) Current float-actuated devices are preferable to conventional pressure-actuated devices and should be maintained until all servo-manometers have been replaced. Float-actuated devices are relatively easily converted to telemetry output by the interfacing of a reasonably inexpensive (approx. $700.) shaft encoder.

(4) A variety of water level sensors should be developed for different site applications.

(5) A training module and program for W.S.C. staff on electronic systems should be developed in the near future.

TABLE 3.1

CAPITAL COST OF FIELD EQUIPMENT FOR STAGE MEASUREMENT

CONFIGURATION		WATER LEVEL SENSOR	RECORDER	POWER SUPPLY	ENCODER	TELEMETRY UNIT	TOTAL COST OF FIELD EQUIPMENT
No Telemetry	Conventional	Servo-Manometer or Stilling Well/Float $4500	Leopold-Stevens A-35, A-71 $2500	-----	Not required	-----	$7000
	Electronic	Servo-Manometer or Stilling Well/Float $4500	EDAS $2300	Photo-Voltaics $450	Required $700	-----	$7950
	Electronic	Pressure Transducer $1500	EDAS $2300	Photo-Voltaics $450	Not required	-----	$4250
Telemetry	Conventional	Servo-Manometer $4500	-----	Photo-Voltaics $450	Required $1500	DCP or DATS $5000	$11450
	Electronic	Servo-Manometer $4500	$2300	Photo-Voltaics $450	Required $700	Transmitter $2500	$10450
	Electronic	Pressure Transducer $1500	EDAS $2300	Photo-Voltaics $450	Not required	Transmitter $2500	$6750

(6) Manual gauges may be suitable for project applications where attendant proximity to the gauge is such that frequent cost-effective measurements can be made. An example of such a project is the monitoring of flow in a small stream following a rainfall event. Manual gauges are not practical from a cost and benefit point of view in regular network operations, and therefore should not be considered for use. The frequency of readings required to produce an accurate stage hydrograph required in regular network operations preclude the economic feasibility of using a gauge attendant to obtain readings.

(7) Manual gauges may be installed in conjunction with water level stations in flood prone areas whenever a backup is required for existing instrumentation i.e. when this instrumentation provides data for critical use such as flood forecasting purposes. However, the integrity of manual gauges must be maintained by regular levelling checks.

3.3 VELOCITY AND FLOW MEASUREMENT TECHNOLOGY

3.3.1 General

Velocity measurements are made to compute discharge based on the velocity-area method. The discharge is used to develop a relationship between flow and stage for the full range of stage. In New Brunswick, approximately five measurements are obtained during ice-free conditions and four measurements are obtained during the period of a consolidated ice cover. This varies from station to station depending upon the reasons for the station, project requirements, geographic location, climate and the stability of the stage-discharge relationship.

Under conventional station operating procedures, one of the most important considerations is that a sufficient number of flow measurements be obtained to clearly establish the relationship between stage and discharge.

The measurement of flow using conventional station operating procedures is a manual operation performed at specific stages. Due to the variability of flow at stations in New Brunswick, it may take a number of years for the development of fully-defined operational

stage-discharge relationships. There is a necessity to check and amend rating curves regularly and to revise records accordingly. There are new instruments being developed for general operational use which will directly measure flow, thus eliminating the requirement for several years of stage-discharge relationship development. This instrumentation falls into the general categories of electromagnetic and ultrasonic flow measurement.

3.3.2 Cup and Vane Current Meters

Both the cup and vane current meters are vertical axes meters whose key features are that their bearing surfaces are located in fairly deep cavities which trap air when the meter is submerged in water. This effectively excludes water and silt from the bearing surfaces eliminating undue wear and resulting change in the meter rating. Extensive experimentation has shown this meter to be rugged, reliable, and suitable to a wide variety of conditions (Inland Waters Directorate, 1983).

The advantages and disadvantages of cup and vane current meters are as follows:

Advantages

- simple mechanical design
- withstands hard usage
- field repairable (but should be recalibrated)
- portable
- can obtain velocity by visual or electrical revolution count

Disadvantages

- vertical and horizontal alignment important
- requires two people to operate due to safety considerations
- susceptible to transverse flows more than propeller type; could over-register low flows
- less accurate in measuring low flows than high flows
- two meters required due to susceptibility to damage and calibration requirements
- subject to freezing
- rating affected if cups damaged or if cups filled with slush ice so that geometry of assembly changes

- pulse count is an electrical - mechanical connection so operating in contaminated water can deteriorate the signal
- bearing can pick up grass and debris so that it is wound on the shaft (but less reaction to sediment than the OTT meter)
- calibration susceptible to type of weight assembly used
- foreign manufacture

Current Developments:

(1) Metal cups are being changed to plastic cups of different geometry.
   - parabolic filled cups more sensitive to low flow velocity and less affected by transverse velocities
   - solid cups can not be filled with slush ice
   - less chance of ice adhesion
   - cost less for cup/rotor assembly (from $125. to $5.)
   - batch rated so cost of rating will go down

(2) Fibre optic signal pickup is being investigated.
   - allows current meter to be used in contaminated water
   - higher precision with increased count (1 count/revolution to become 16 counts/revolution)
   - may shorten measurement time
   - negative: increases cost of current meters
   - reduces internal friction of current meter as it is not a contact device so the sensitivity for low flow velocity measurement is enhanced
   - immune to environmental effects; not affected by freezing

Desirable improvements are:

- digital readout and data storage;
- compatibility with electronic data acquisition devices;
- shorter measurement time; and
- separate computational packages.

In New Brunswick, cup and vane current meters are used extensively. Each hydrometric technician has two open water and winter Price AA current meters, and a Pgymy current meter. Price AA meters cost approximately $750. each and Pgymy meters cost approximately $700. each. The number of meters in use will make any nationwide change expensive.

3.3.3 Propeller-Type Current Meters

Propeller-type current meters are horizontal axes meters whose main attribute is lower sensitivity to turbulence making them suitable for low flow measurement or for specific applications such as measurements from boats. Hence, they find specific applications in Canada in the moving boat flow measurement techniques.

The advantages and disadvantages of propeller-type current meters are as follows:

Advantages

- greater accuracy and precision than cup and vane current meters
- lower susceptibility to transverse flows
- higher electrical pulse count resolution per revolution than now possible with a vertical axis meter
- less affected by slush ice as there are no cups that can be filled
- compatible with the moving boat technique

Disadvantages

- more expensive than cup and vane current meters
- less durable than cup and vane current meter
- not field repairable
- subject to freezing (probably more than for cup meters as less space exists between the propeller and shaft)
- inaccuracies may result if ice adheres to propeller changing its pitch
- physically larger than comparable cup and vane current meters
- visual count of revolutions impossible
- electro-mechanical signal pickup affected by conductivity
- susceptible to damage by sediment
- electromechanical pickup is less simple and requires delicate adjustment
- foreign manufacture

Constraints are:

- little experience with use in New Brunswick;
- higher cost than cup and vane current meters; and
- not feasible for winter discharge measurements.

Desirable improvements are as follows:

- compatibility with general electronic acquisition devices;
- shorter measurement time; and
- digital readout and data storage.

The OTT Meter currently used in New Brunswick is a propeller-type current meter.

3.3.4 Portable Magnetic Flux Meters

Electromagnetic current meters are based on Faraday's Law of electromagnetic induction. As a liquid, in this case water, cuts the lines of magnetic flux, an electromagnetic force (Emf) is induced in the water and is picked up by electrodes. The amount of induced Emf is proportional to the strength of the magnetic field and the velocity of water.

The advantages and disadvantages of portable magnetic flux meters are listed below.

Advantages

- highly portable
- digital readout
- two dimensional flow measurement
- sensitivity comparable to mechanical current meters
- less susceptible to filling

Disadvantages

- cost greater than for mechanical current meters
- more complex than mechanical current meters
- subject to physical damage
- affected by density changes (due to temperatures, salinity or presence of contaminants)
- application affected by cold weather sensitivity
- battery cells drain power in cold weather (has to be kept in warm enclosure at night)
- total probe submersion required
- not presently practical for high water use
- needs a solid support, if velocity or depth high
- can not be used if electronics fail
- possibility of reading wrong scale if multiple scales on meter
- signal conveyance cord has a larger diameter which

may affect accuracy
- potential drift so recalibration necessary
- foreign manufacture

Constraints of portable magnetic flux meters are as follows:

- few spare parts since not widely used; and
- maintenance not available presently in Canada.

Generally, portable magnetic flux meters are used for scientific studies and hydroelectric ratings; for example, the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) and Fisheries and Oceans Canada use them.

3.3.5 Fixed Magnetic Flux Flow Measurement Devices

The fixed magnetic flux flow measurement device uses a coil buried below the river bed or bridged across the channel to generate a vertical magnetic field across the full channel width. Electrodes set into opposite banks of the channel pick up an induced potential generated by water flowing through the magnetic field. Electrical control equipment drives current through the coil and measures an induced potential proportional to the average velocity of water (Redland Automation, 1981).

A feature of this device is the fixed insulating membrane which attenuates the signal that may otherwise be caused by the electrical conductivity of the streambed.

The advantages and disadvantages of fixed magnetic flux flow measurement devices are listed below:

Advantages

- measures flow directly (total mass movement not velocity)
- measures very low flows
- not affected by changes in channel conveyance
- does not require rating revision
- non-intrusive, instantaneous and continuous
- data can be readily transmitted through existing devices
- not affected by presence of weeds or sediment
- no minimum depth requirement
- reduces site visits to maintenance checks

Disadvantages

- extensive civil works required to "insulate channel"
- non-portable and site-specific
- high installation cost due to requirement for stream diversion
- high cost ($80,000)
- risk of damage by ice or debris
- have to remove if non-operational
- requires controlled environment for electronics
- requires large AC power supply
- foreign used and manufactured

Constraints and desirable improvements are as follows.

Constraints

- installation and calibration must be conducted by highly experienced personnel;
- costly;
- no background experience or maintenance capability existing; and
- application to ice jam prone rivers risky.

Desirable Improvements

- capability to measure natural magnetic fields rather than induced magnetic fields.

3.3.6 Portable Ultrasonic (Doppler) Devices

The measuring principle adopted by these devices is that an ultrasonic pulse transmitted at an angle into the flow is reflected by moving particles in the flow and received with a shift in frequency. The frequency shift observed is proportional to the velocity of the particle which instigated the reflection of the pulse.

In moving boat configuration, the system uses four pulse generating transducers to measure both flow and boat velocities simultaneously.

The advantages and disadvantages of portable ultrasonic (doppler) devices are listed below.

Advantages

- rapid measurement
- measures two dimensional flows
- integrates entire depth or any portion of depth
- not affected by low flows as compared to conventional moving boat techniques
- can presently be used on large rivers using moving boat technique

Disadvantages

- cannot be used during ice-covered period
- not field repairable
- not capable of withstanding hard usage
- costly ($80,000)
- accuracy reduced by boundary effects
- accuracy affected by channel geometry
- has to be supported to a high degree by electronic signal and data processing equipment
- foreign manufacture
- non-Canadian maintenance

Constraints

- not widely used, difficulty in getting parts or maintenance.

3.3.7 Semi-Portable Ultrasonic Velocity Measurement Devices

The ultrasonic flow meter measures water velocity by determining the travel times and sound pulses moving in both directions along a diagonal path between transducers mounted near the bank of the stream. The water velocity indicated by the system is computed based on the principle that the point-to-point travel time of sound is longer upstream than downstream and that travel times can be measured accurately by electronic devices.

A transportable ultrasonic flow meter is based on the concept that the transducers remain fixed at their location at the site and the signal processing electronic component is moved from one site to the other. The

requirement is that the site characteristic information e.g., path length, path angle to flow etc. can be readily programmed into the signal processing system.

The transportable ultrasonic velocity measurement devices have the following advantages and disadvantages.

Advantages

- measurements can be quickly obtained
- velocity, stage (at 2 pts.) and temperature can all be measured in one package
- data can be readily transmitted
- power supply is portable and renewable
- device can be left at site for rating then removed
- cheaper than other non-mechanical devices
- Canadian manufacture

Disadvantages

- there must be a log velocity distribution unless multi-level transducers installed
- cannot be used on rivers wider than 1000 m
- accuracy of depth measurement questionable
- channel geometry must meet a minimum depth criteria, minimum depth = $27\sqrt{L/freq}$
- not field repairable
- cannot get point measurements
- transducers subject to ice and debris damage
- cannot be downstream of rapids as entrapped air affects the signal across the channel
- cannot be used in streams with large amounts of aquatic vegetation because oxygen generated by this vegetation breaks up the signal across the channel
- affected by salinity and sediment
- not tested for underice operation

3.3.8 Fixed Ultrasonic Velocity Measurement Devices

These units are identical in operating principle to the transportable ultrasonic flow meters. They obtain their fixed status on the basis of the transducer mounting configuration which can be multi-layered, cross paths or both. Due to the transducer installation costs and the increased information required for signal processing, these systems cannot be readily transported from site to site.

Advantages and disadvantages are as follows.

Advantages

- measurements can be obtained quickly
- data can be readily transmitted
- velocity, stage (at 2 pts.) and temperature measured all in one package
- instrumentation more sensitive than for portable devices

Disadvantages

- must have a log velocity distribution unless multi-level transducers installed
- cannot get point measurement
- bulkier instrumentation at site than portable devices
- controlled environment and AC power required
- non-field repairable
- cannot be used in areas where signal will be affected by salinity, dissolved oxygen, sediment or excessive weed growth
- transducer subject to ice and debris damage

3.3.9 Tracers

Two methods have been utilized by the Water Survey of Canada in determining discharge by dye dilution. They are the constant-rate injection method and the slug injection or total recovery method.

In the constant rate injection method, a dye solution of known concentration is injected at a constant rate at a point upstream of the measurement section. Total mixing must occur between the two points to ensure accurate results. Water samples are then obtained at the measurement section and analyzed using a fluorometer to determine dye concentration. Streamflow can then be calculated using the formula:

$$Q = \frac{C1}{C_2 - C_b} \times q$$

where Q is the flow in the stream;
C_1 is the concentration of the injectant;
C_b is the background fluorescence of the stream;

C_2 is the concentration of dye at the sampling section; and
q is the discharge rate of dye solution into the stream.

In the slug injection or total recovery method, a known volume of dye solution of known concentration is dumped into the stream, upstream from the measuring section. The dye cloud may be sampled by either continuous fluorometer sampling or by repeated grab sampling. Extensive sampling must be carried out in order to completely define the concentration time curves.

The stream discharge can be calculated using the formula:

$$Q = \frac{C_1 V_1}{(C_a - C_b)T}$$

where C_1 is the concentration of solution put in stream;
V_1 is the volume of the solution;
C_a is the average concentration measured during the time of dye passage;
T is the time of dye passage; and
C_b is the background fluorescence of the stream.

The slug method is considered to be less accurate than the constant-rate injection method.

Tracers have the following advantages and disadvantages.

Advantages

- time of travel provided
- flow can be measured under situations where other measurements are not practical as through a slush field
- material inexpensive

Disadvantages

- visually, physically and chemically contaminates river
- manpower intensive
- single one-time measurement restricts use to special studies
- exact methods must be used, regardless of whether continuous or slug injection
- laboratory follow-up required

3.3.10 Comments on Costs and Accuracy

Table 3.2 gives the capital costs of flow measurement equipment.

The trend is towards greater automation of the hydrometric network. At the present time, for a site suitable for automation, capital costs will triple but field operational costs will be reduced by almost 2/3. In the future, capital costs are expected to be reduced. A pilot project may verify expected costs.

For the fully automated station, such as a station with a velocity measurement device described in subsections 3.3.5, 3.3.7 or 3.3.8, there will be no rating requirement or provisional data period. The data will be near real-time. Accuracy will improve because the number of measurements are increased. "Estimated" records will be eliminated as there is no need to extend the rating curve. Any error due to gaps in the stage-discharge relationship will be eliminated as actual continual measurements at the site will be available.

3.3.11 Recommendations

(1) Cup and vane current meters with digital readout and data storage devices compatible with electronic data acquisition should be developed by the responsible federal agency (Environment Canada).

(2) Improved cup and vane current meters with solid plastic cups and fibre optic signal pickup should be incorporated into the New Brunswick hydrometric program. This will improve the accuracy of streamflow measurements during low flow periods and lessen the possibility of error at the site. Fibre optic signal pickup provides opportunity for more pulse counts per revolution and thus increased sensitivity. Because of the increased sensitivity to low velocities, the accuracy of streamflow measurements during low flow periods will be improved. Reduced scatter of discharge measurements on the stage-discharge curve at lower flows will result in a reduced need for field visits. There will be a time-saving in the field and in the data reduction and analysis through automation of the computations. There should be provision made for acquisition of these devices within the next three years.

TABLE 3.2

COMPARISON OF PROJECTED ANNUAL COSTS PER STATION FOR

ULTRASONIC AND CONVENTIONAL FLOW MEASUREMENTS IN NEW BRUNSWICK

Method	Summer*			Winter*			Equipment							
Conventional	Salary	Trip	Misc.	Salary	Trip	Misc.	Vehicle	Boat	Cableway	Current Meter	Reel	Snow Mobile	Ultrasonic	Total Annual
Boat (2 persons)	600	270	250	500	200	200	200	100		75	60	100		2555
Cableway (1 per.)	300	135	250	500	200	200	200		150	75	60	100		2170
Bridge (1 per.)	300	135	250	500	200	200	200			75	60	100		2020
Wading (1 per.)	300	135	250	500	200	200	200			75	60	100		1960
											Average Annual		2176	
Ultrasonic*	240	108	100	125	50	50	70	40		75	60	100	2000	3018

* NOTE: A normal conventional flow measurement program requires that 5 summer and 4 winter measurements are made. For the ultrasonic method, 2 summer and 1 winter measurement are allocated for flow meter calibration purposes.

(3) Conversion to propeller-type current meters should not be considered as there is little to gain over cup-and-vane current meter technology.

(4) Development of magnetic flux and ultrasonic velocity measurement devices should continue with emphasis on acoustic (ultrasonic) devices, with the objective of automating streamflow data collection by the end of the century. Automation will reduce manpower requirements in the field and hence is expected to increase the effectiveness of the hydrometric network operations.

(5) An installation in New Brunswick of a fixed ultrasonic velocity measurement device, or similar device, should be undertaken within the next three years and a pilot project undertaken thereafter to test this device and train staff on its operation and maintenance. The rate and extent of future automation will depend upon the results of this pilot project.

Special considerations should be given to installation of the device at a station that could be operated throughout the winter and ice breakup periods.

The device costing approximately $17,000 will provide the necessary field verification of the capability of these instruments to measure flow under difficult conditions eg. during breakup, and will provide a basis for eventual operational use of these velocity measurement devices.

(6) Tracers should not be considered for operational use. The dyes are perceived by the public to be a contaminant in the watercourse. Also, the method is manpower intensive, costly, and requires laboratory follow-up.

3.4 TELEMETRY: HYDROMETRIC COMMUNICATION LINKS

3.4.1 Definition and General Requirements

Hydrometric communication links are defined as those segments of a data handling system which permit the transfer of data from one point to another either by

satellite or landline communication systems. Figure 3.1 illustrates the system proposed for use by the Water Resources Branch of Environment Canada.

In general, hydrometric communication links should fulfill the following requirements.

- near real-time data transmission from hydrometric stations as user demand warrants;
- relatively inexpensive system;
- highly reliable system;
- secure system.

3.4.2 Desirable Features

Desirable features of hydrometric communication links include:

- compatibility with national systems
- security of supply i.e. a system based upon several manufacturers of equipment to keep competition up and costs down, and to ensure that reliable maintenance can be carried out
- capability to have multiple sensors so as to allow integration with other networks
- two-way communication especially if sensors have to be remotely calibrated
- near real-time interrogation of data collection instrumentation
- restricted access for use by selected agencies with multiple communication links installed to meet different user requirements when necessary.

3.4.3 Landlines

Landline communication is considered the use of standard telephone communication systems where specifications and rates of pay for use are established by the New Brunswick Telephone Company.

Advantages

- real-time data collection
- flexibility in sampling frequency
- data can be withdrawn when and if required
- two-way communication with the device at the site (for data transfer, remote programming) possible
- operation of remotely programmable devices possible

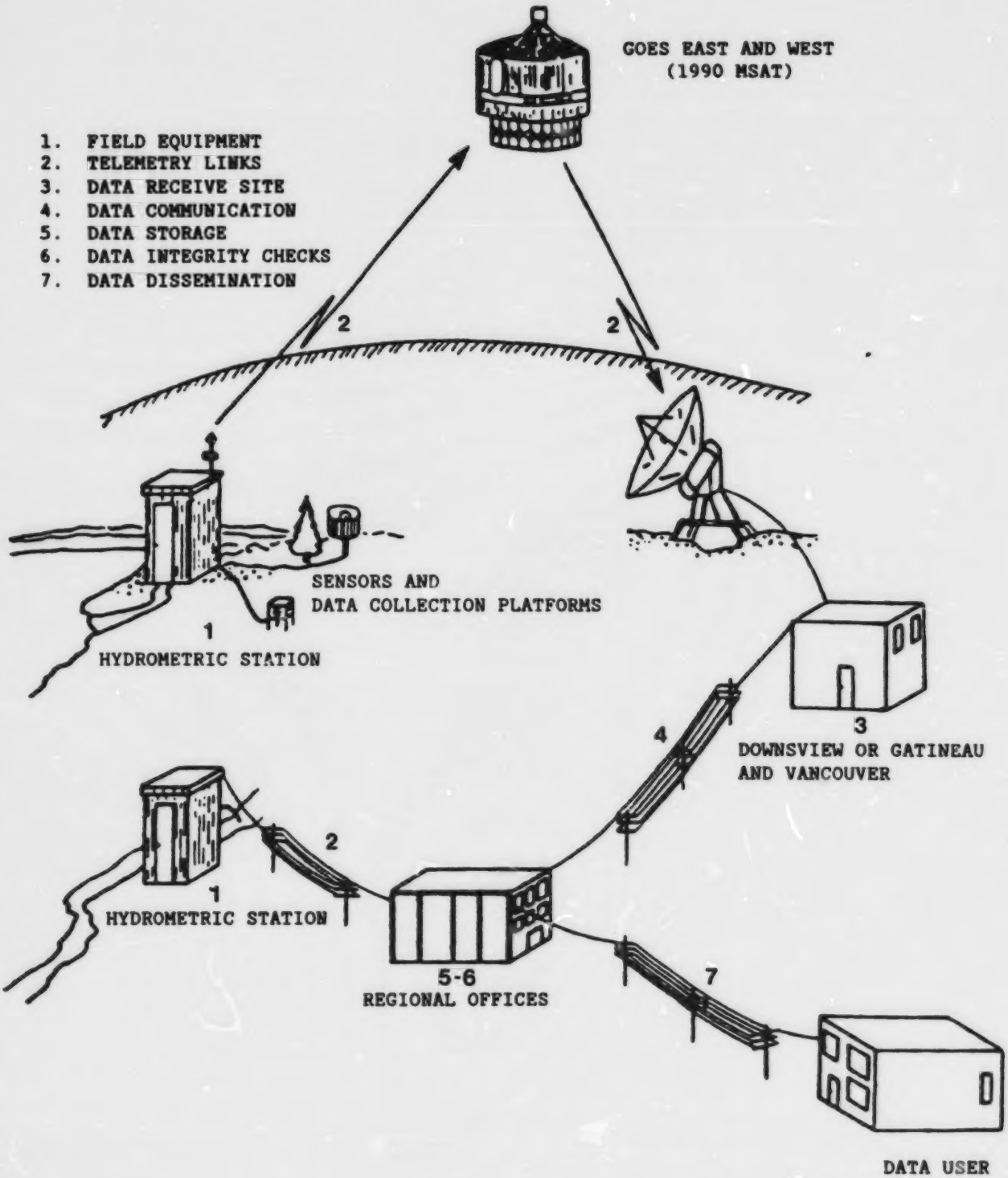

Figure 3.1 WRB Real Time Data Handling System

- no limit (except cost) to range of access
- direct public access possible
- interface can be rented or purchased cheaply
- user bears no cost in maintaining communication lines as the communication link has to be maintained for other customers and the general public.

Disadvantages

- installation costs could be high if communication lines not readily available nearby
- prone to interference by natural causes during critical events (i.e. during lightning storms, high winds or floods)
- maintenance of communication lines at the discretion of the communications utility
- telephone equipment as distributed by telephone companies will not operate at temperatures below freezing; devices meeting these requirements are special products which are supplied only by a limited number of manufacturers (eg. Leopold and Stevens)
- not practical (unless with dedicated lines) to interrogate at short time intervals (several times per hour)
- lines readily accessible by public who could tie-up lines during critical periods.

3.4.4 High Frequency (HF) Radio

High frequency (HF) radio is the use of commercially available radio systems where the transmission and protocol is dictated by the systems capability and the federal regulatory agency. The rates of pay for use is dependent upon the owner of the system. If a private system is considered, licensing will have to be arranged through the Department of Communications.

The New Brunswick Electric Power Commission (N.B.E.P.C.) operates a limited system for transfer of hydrometric information along the Saint John river.

If serious consideration is given to the development of an HF radio system, or extension of an existing system, the availability of line-of-sight for repeater stations

must be investigated. The following advantages and disadvantages of HF radio as a hydrometric communications link should also be considered.

Advantages

- continuous
- dedicated to user requirements
- suitable for two way communication (can interrogate at any time or frequency)
- message length not a problem
- multiple sensors possible
- more reliable than landlines but less reliable than data transfer using satellites
- power requirements depend upon frequency of use

Disadvantages

- radio frequency allocation is difficult and expensive
- multiple repeater stations required in rugged terrain making system expensive
- repeater stations need AC power sources
- user responsible for maintenance
- direct line-of-sight required
- a national system is difficult to implement due to lack of complete areal coverage although regional use is possible

3.4.5 Meteor Burst Communications

Taking advantage of the multitude of particle trails left by meteor break-up in the atmosphere, VHF radio waves can be reflected between a transmitter and a receiver system, when the radio waves are bounced off meteor particles.

The process can be performed in various ways, but typically a transmitter at the base of information gathering could signal the remote receiver to begin data transmission. The base transmitter would signal continuously until meteor burst. This signal starts the remote transmitter, and once the information being sent has been received the base transmitter could then signal the remote transmitter off.

This operation has an effective range of 320 km to 1930 km between the transmitter and receiver; which have optimum operational frequencies of 30-50 MHz.

For any specific area, (where meteor burst communications are undertaken or planned), meteor particles appear between ten and sixty times an hour and may last between one tenth of a second to ten seconds (with early morning and fall equinox tending to be periods of highest meteor activity). This provides plenty of opportunity for periodical information collection.

The advantages and disadvantages of meteor burst communications are listed below.

Advantages

- high reception (85% plus)
- privacy
- no interference with other users
- no potential for company or foreign country to end communication link
- no unauthorized agencies can get data
- instantaneous
- could cover the entire Province of New Brunswick with only two receiver stations

Disadvantages

- high cost (approx. $10,000 per platform)
- data collection devices more expensive than data collection platforms to be used in satellite data transfer systems
- receive sites fairly expensive - $ C 150,000 to $ C 250,000
- high installation cost
- maintaining station integrity could be a problem as there is only one North American manufacturer of equipment
- market control over costs could be a problem as there is only one North American supplier of equipment
- an operating protocol would have to be defined as the procedure for acquiring data is different from other systems
- interference in transmission due to severe storms possible
- higher power requirements (depending upon frequency of use) than satellite systems
- less portable than satellite-based systems

3.4.6 Geostationary Satellite Systems

A satellite in geostationary orbit makes one revolution per day and therefore stays at a near constant altitude over the same point above the equator. Thus constant coverage of the footprint area is obtained. A satellite designated for environmental purposes has the capability to transmit data and to provide imagery of the area under surveillance.

The geostationary satellite system currently used in Canada is the Geostationary Operational Environment Satellites (GOES) operated by the U.S.A. National Oceanic and Atmospheric Administration (N.O.A.A.) as part of the global observation system of the World Meteorological Organization's World Weather Watch. The GOES system consists of two geosynchronous satellite platforms located 36 000 km over the equator at 75°W and 135°W longitude providing coverage of most of the Western Hemisphere except for the polar regions.

Canadian data is currently retrieved through the National Environmental Satellite Data and Information Service (N.E.S.D.I.S.) of N.O.A.A. located in Suitland, Maryland, U.S.A. Distribution of data through N.E.S.D.I.S. is not expected to continue beyond 1989 (due to the American agency's data distribution policy). Environment Canada is currently in the process of acquiring two direct readout ground stations to be located at Downsview, Ontario and Vancouver, British Columbia. The two locations are expected to commence data reception during early 1988. If so, N.E.S.D.I.S.'s cessation of data distribution should not affect Canadian satellite data reception.

A proposed Canadian satellite system MSAT (Mobile Satellite) is expected to be operational by 1990. The MSAT satellite is expected to be located at 105°W longitude and to have a footprint covering all of Canada except a few Arctic islands.

The MSAT system will be used for mobile communications which may be defined as communication between two or more stations at least one of which is mobile by virtue of its installation in a vehicle or by virtue of its transportability to a site (Goodison, Langham and Athanassiades, 1983). Remote hydrometric data transmission from data collection platforms (DCPs) is considered

mobile communications. MSAT will alleviate many of the disadvantages due to one-way communication and will likely be more accessible as it is a Canadian system.

MSAT will be owned by Telesat Canada and the federal government. A user fee (yet unknown) is expected to be levied.

The advantages and disadvantages of geostationary satellite systems as communication links are listed below.

Advantages

- constant and predictable coverage
- different time slots can be requested
- small ground transmitters with low power requirements
- satellite link presently provided at no cost to the user; a moderate cost is expected in the future
- reliable
- no restrictions on location providing line-of-sight to satellite possible
- fewer local events knock out communications, as communications largely unaffected by floods or high winds

Disadvantages

- only foreign satellite systems (eg. GOES) available at this time but MSAT may solve this problem
- only one-way communication at present
- time slot restrictions exist due to ground systems capability
- frequency of communication may be adjusted by natural events (eg. thunderstorms)
- a receive site is required for operational purposes
- transmitters located in deep valleys may not be able to transmit to the satellite

3.4.7 Polar-Orbiting Satellite Systems

In a polar orbit, a satellite observes the earth as the planet revolves beneath it. The orbit conveys a satellite above the earth's surface from the vicinity of one of the earth's poles across the equator to the opposite pole and then continuing on towards the equator and other pole again. A satellite can be placed in a polar orbit so as to cross any given latitude at approximately

the same local time every day. This is termed a sun-synchronous orbit because the relationship between the satellite's orbital plane and the centres of the earth and the sun remains constant (Paulson, 1986).

Transmission to polar-orbiting satellites is possible when a direct line-of-sight exists between the ground station and the satellite. This is expected to be achieved 8 to 10 times per day in New Brunswick.

The polar-orbiting satellite system used in Canada is ARGOS. It is a cooperative effort of the Centre National d'Etudes Spatiales (C.N.E.S., France), the Naticnal Aeronautics and Space Administration (N.A.S.A., U.S.A.), and the National Oceanic and Atmospheric Administration (N.O.A.A., U.S.A.).

The French ARGOS system onboard N.O.A.A. meteorological satellites is primarily intended to locate fixed or mobile platforms and to collect environmental data from these platforms. The data can be accessed by telephone or telex from a data processing and distribution centre in Toulouse, France, a few hours after acquisition by satellites (Taillade, 1983). There is also a data reception centre in the United States.

The ARGOS Platform Transmitter Terminal (PTT) is a small, battery-operated radio transmitter that costs approximately $2,000 each and that can be used for environmental data collection and for position location (Paulson, 1986). It includes an ultrastable oscillator, antenna, digital message generation logic, sensor interfaces, and a power supply (Taillade, 1983). PTTs can transmit hydrometric data messages containing 32 to 256 bits of data.

The ARGOS system PTTs are relatively straightforward to install as it has a random access mode of operation and there is no need to maintain a precise time-base. The Water Resources Branch of Environment Canada presently has one operational ARGOS system PTT.

Advantages

- high reliability
- can transmit out of locations unsuitable for geostationary purposes

- relatively unaffected by local events
- low cost (but not free)
- low power requirements

Disadvantages

- satellite may not be in position when transmission required
- reception is in foreign countries thus international message link required
- unacceptable delays and landline problems may arise in the transmission of data
- transmission depends upon the orbiting characteristics (frequency, path) of the satellite
- only one-way communication possible
- transmitters can be knocked out during thunderstorms

3.4.8 Comments on Cost and Accuracy

The most cost-effective national telemetry system is the GOES satellite system. It is projected that the operational cost of a telemetry system based upon the use of these satellites and the operation of Canadian satellite receiving stations will be a maximum of $200 per data collection platform per annum. In some cases, landline or regional high frequency radio systems may be less expensive to operate but will in most instances be more expensive with respect to instrumentation and maintenance. Various agencies have conducted studies and in all cases they have reverted to the national system which was the most cost-effective.

The reliability of a satellite-based communication system has been quoted as being very good (having a bit loss rate of less than 10^{-8}). This is somewhat increased at the ground station level, but can be overcome by choosing appropriate hardware and incorporating redundancy in equipment. Hence, accuracy is ensured as far as it is dependent upon the acquired data (i.e. no record loss).

3.4.9 Recommendations

(1) In the foreseeable future, the geostationary satellite link should be the preferred communication link because it is a reliable, low-cost, and secure system for near-real time data collection of several parameters.

(2) Consideration should be given to two-way communication capability and the acquisition of multi-parameter data as determined by an integrated hydrometeorological data collection network.

(3) In view of the National Environmental Satellite Data and Information Service (N.E.S.D.I.S.) proposal to discontinue direct distribution of data from its Suitland, Maryland location, it is highly recommended that the Coordinating Committee encourage and support Canadian authorities in taking action to ensure its data reception capabilities. This action is now underway with the establishment of two satellite receiving sites in Canada. The support requirements are expected to be confined to the cost of operating these receiving sites which are expected to be $200. for each data collection platform per annum.

(4) A field evaluation using MSAT should be made once it is available and recommendations should follow this evaluation.

3.5 TELEMETRY: DATA ACQUISITION AND COMMUNICATION INSTRUMENTATION

3.5.1 Definition and General Requirements

Data acquisition and communication instrumentation are those devices located at a hydrometric station capable of being interfaced with environmental parameter (e.g. water level) sensors, receiving and converting the output from these sensors, and then formatting and transmitting the data by means of the communication link in use.

In general, data acquisition and communication instrumentation should fulfill the following requirements:

- low cost instrumentation;
- high reliability, and
- security.

3.5.2 General Remarks

Rapidly progressing technology will result in significant improvements to existing systems with programming capability allowing for greater flexibility in data collection. This should be encouraged and the results applied.

There is a trend towards multi-parameter acquisition. The integration of data collection networks is possible.

Increased automation in data collection is foreseen. Data acquisition and communication instrumentation should be considered when evaluating the hydrometric network. Instrumentation (discussed by the Technology and Operations Subcommittee) has been limited to the following: telemarks, DATs and DCPs. Although other instrumentation is available, cost or technical complexity often limit their use in an operational network.

3.5.3 Telemark II (Electronic Telemark)

The advantages and disadvantages of electronic telemarks are as follows:

Advantages

- reasonably cheap
- compact and lightweight
- very low in power requirements
- has its own internal modem

Disadvantages

- no display
- limited to two parameters
- limited storage

3.5.4 DATs

A shaft encoder, usually driven by a float, provides water depth data with a resolution of 1 mm to a central processing unit (CPU).

The program stores this data and upon command from a remote CPU or user terminal, the data is dumped over an E.I.A. interface. Operator input is allowed to set header information, year, day, time, sample interval and

level. The level adjustment allows setting to a particular datum. Data is stored in blocks of 12 consecutive samples, to a maximum of 60. Command format is very inflexible and must be precisely followed.

The advantages and disadvantages of DATs are as follows:

Advantages

- storage of data with landline communication possible
- frequency of data acquisition can be reset remotely
- weekly interrogation possible
- display allows for field viewing
- Canadian-made (by Canadian Applied Technology)
- easy to install

Disadvantages

- poor operational record
- prone to program loss due to power interruptions or surges
- high power consumption
- limited to one sensor
- operational problems in cold temperatures requiring heated shelters for both instrumentation and modem
- not field repairable and a poor record on return after repairs

DATs was the first electronic device with storage capabilities which operated with a landline communication link.

3.5.5 Data Collection Platforms (DCPs)

Data collection platforms accept signals from sensors measuring a host of water resource and other environmental parameters, convert the signal to digital values, store the data and broadcast these data at intervals to satellites in geostationary or polar orbits. The satellites relay the data to ground stations from which they are distributed to network operators and/or users. Data Collection Platforms have the following advantages and disadvantages.

Advantages

- capable of unattended operation at remote sites using satellite communication links
- multi-sensor interfacing capability

- low power requirements
- will accept analogue events and parallel digital and serial digital signal inputs
- easily portable
- easy to install
- easy to connect/disconnect to sensor parts
- field maintenance consists of whole unit replacement
- reasonably easy to program and activate in the field
- current models have low maintenance costs
- several manufacturers including Canadian

Disadvantages

- most exhibit inflexible data acquisition format
- one-way communication
- limited data storage (approximately 350 characters)
- not field repairable
- more expensive than other data acquisition and communication instrumentation, eg. telemarks
- no displays: verification of sensed data must be through a programming unit

3.5.6 Comments on Cost and Accuracy

The cost of a general purpose hydrometric data acquisition system should not exceed that of conventional data recording equipment (e.g. a strip chart recorder). Where a requirement exists for an enhanced station, e.g. a complete hydrometeorological station, cost should be in proportion to data acquisition capability. Communication costs would be determined by the communication link used.

The accuracy of data acquisition and communication systems (i.e. the accuracy of converting sensor output to engineering units) should be an order of magnitude greater than the desired accuracy of the parameter sensed. This criteria is met by most units currently in use. However, current systems are designed for specific applications and hence the proliferation of these systems increase maintenance cost and complexity. It is desirable to develop one system which would address the full sprectrum of data acquisition and communication needs but still adhere to the above cost and accuracy requirements. The advantage of having a national standardized system will be that Environment Canada can order a greater number of units thus driving down costs of manufacturing and maintenance.

3.5.7 Recommendation

An electronic data acquisition and telemetry system (Figure 3.2) is currently under development (for Environment Canada). If evaluation of this system is positive, it is recommended that this system be designated as the standard unit for operational use in the New Brunswick hydrometric network. In its present configuration, the system is expected to cost no more than present data acquisition systems, but because of its inherent reliability and flexibility in application, it is expected that its use will reduce data loss and hence improve accuracy. In the interim, where one or two parameter data acquisition and one-way communication will suffice, it is recommended that Telemark II units be installed.

3.6 SPECIAL APPLICATIONS

3.6.1 General

In this section, three applications are presented for which operational flow measurement technology (and procedures) are still in the development stages. The section outlines the current level of understanding and makes some recommendations as to the possible application of new technology.

New Brunswick rivers are covered by ice for several months each year. This modifies the channel and causes a change in the stage-discharge relationship. The capability to measure streamflow to the same level of accuracy as for open water (ice-free) conditions does not exist. This is especially true during the breakup period when discharge measurements are difficult or impossible to obtain.

Many New Brunswick rivers have tidal reaches. Estuarial flow measurement would allow these rivers to be gauged near their outlets to the sea (or larger estuary) in order to get a more accurate representation of total basin discharge.

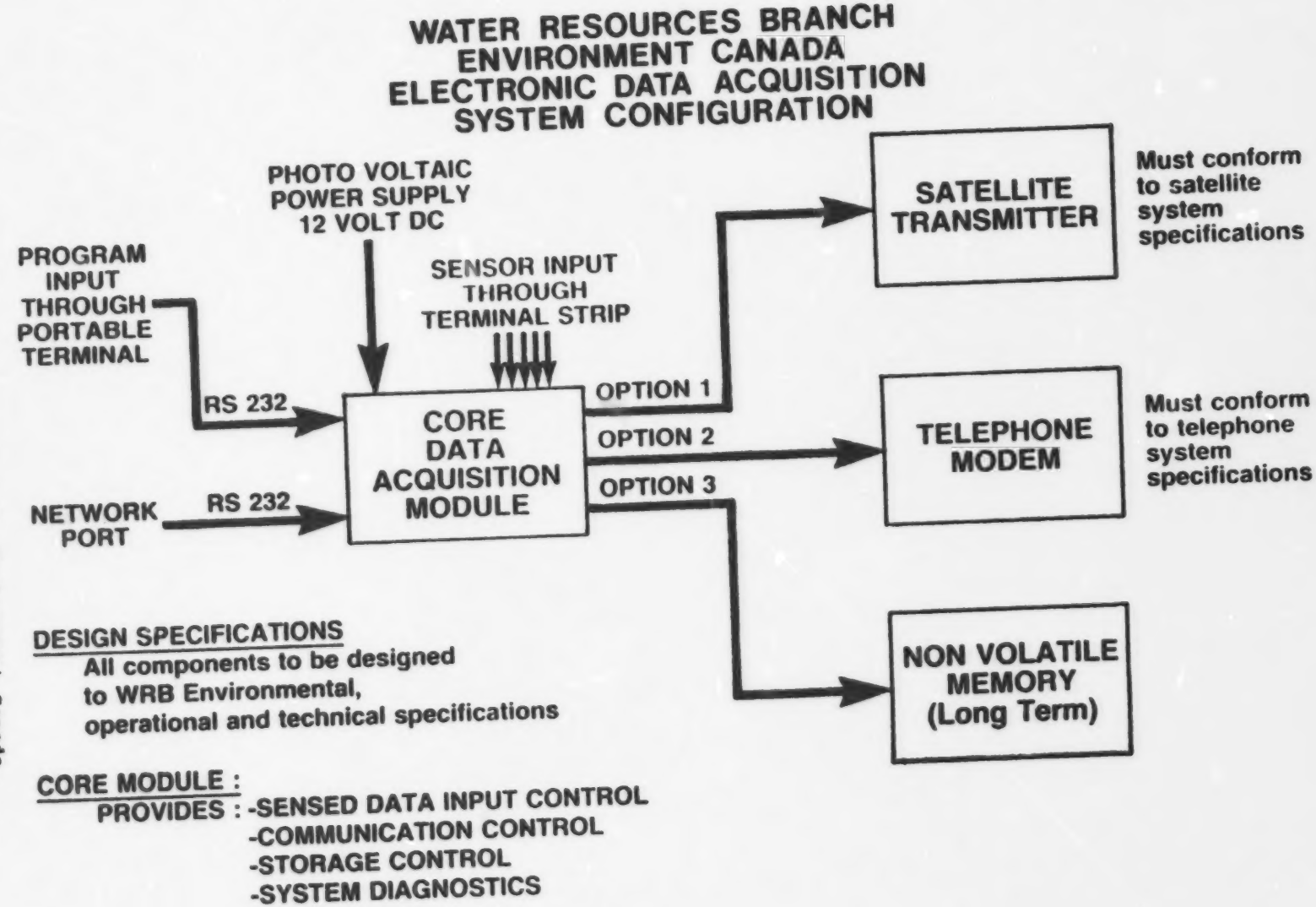

Figure 3.2 Water Resources Branch, Environment Canada,
Electronic Data Acquisition System Configuration

3.6.2 Flow Measurement (and Estimation) during Periods of Ice Cover

3.6.2.1 Current Practice

Winter discharge measurement during periods of ice cover are obtained once a month at most hydrometric stations in New Brunswick. At selected stations where the data are required for flood forecasting or special studies, discharge measurements are obtained twice per month during the period of consolidated ice cover.

Empirical methods are used to provide estimates of discharge between successive winter measurements. These empirical methods have been developed to apply a stage shift during periods of ice cover to permit the use of open water stage-discharge relationships. These methods include a backwater or shifting control method; an interpolated-discharge method; a hydroclimatic comparisons method; and a discharge ratio method. A detailed study of the various methods was undertaken by Rosenberg and Pentland (1966). Different methods seem to be more applicable to different sizes of river and to different hydroclimatic regions.

In the annual discharge publications of the Water Survey of Canada, discharges during an ice cover period are denoted by B and it is generally considered that these measurements are less accurate than for open water conditions.

3.6.2.2 Definition of Problem

Some problems with obtaining winter discharge measurements are that:

(1) an ice cover changes the effective area of flow making the stage-discharge relationship invalid, and increasing the resistance to flow;
(2) instrumentation that are modified or configured to withstand more severe climatic or environmental conditions must be used;
(3) measurements are less accurate under the best of conditions than for open water periods; and that
(4) a winter measurement program is more expensive.

The latter two problems are dealt with in more detail below.

Winter discharge measurements taken during an ice cover period are less accurate than for open water periods because:

(1) it is more difficult to determine the effective flow area;
(2) flow velocity is generally lower increasing the impact of normal measurement uncertainties;
(3) winter discharge measurements may not be indicative of daily discharge (many factors affect flow surges);
(4) meters may be in error (due to ice adhering to rotor and cups); and
(5) erroneous winter discharge measurements affects flows for half of the periods between flow measurements before and after measurements.

The winter field program is expensive for a number of reasons. Winter discharge measurements are more time-consuming and hazardous. For safety reasons, two technicians are often required. Weather conditions often cause delays and scheduling problems. Access to hydrometric sites is more difficult and auxiliary vehicles (eg. snowmobiles) or additional equipment (eg. snowshoes) are often required.

3.6.2.3 Discussion

Nashwaak River Studies:

The flow conveyance capacity of ice covered rivers has been investigated on a nearly straight approximately 400 m long reach of the Nashwaak river near Durham Bridge by graduate students of the Department of Civil Engineering, University of New Brunswick, under the supervision of Dr. Kersi Davar. Burrell (1981) stated that the effects of slush, frazil and anchor ice on resistance coefficients, slope and thus flow conveyance are significant in shallow rivers. He pointed out that the cross sectional area of the flow section is difficult to determine when the ice cover has a very rough or irregular undersurface or when slush or anchor ice causes partial blockage of the flow section. MacGougan (1984) determined that the presence of slush-ice adhering to the undersurface of the ice cover increased the resistance coefficients to values greater than those of adjacent sub-areas without slush-ice and that values of the resistance coefficients for the bed zone were larger for open-water than ice-covered conditions. He

stated that resistance coefficients of the bed zone are generally larger than the resistance coefficients of the ice zone although exceptions occurred. Hendriksen (1986) concluded that the binary law of velocity distribution can be successfully applied to flow in shallow narrow channels and without ice cover and large relative boundary roughness even in cases where the Prandtl-Von Karman method would lead to unrealistic results for the resistance coefficients n and f. He also stated that the binary velocity distribution approach, while having some limitations in areas of very low flows, generally appeared to give more consistent and acceptable results than those obtained from reach analysis using water surface slopes. The work of these graduate students have added to the general body of knowledge about the resistance to flow caused by an ice cover and thus added to the information available on flow conveyance of watercourses.

The Santeford and Alger Model:

Santeford and Alger (1984) proposed a theoretically based model which allows for a direct prediction of the underice flowrate using indicated stage, float depth of the ice, and the open-water stage-discharge relationship. The Manning's equation was written in terms of a geometry function ($AR^{2/3}$) and an energy term ($S^{1/2}n$). It was then determined that the uniqueness of the individual stage-discharge relationship is the functional relationship between stage and the energy term. For an equal flow condition both with and without an ice cover, the following was developed:

$$\frac{D_o}{D_i} = (0.759)(X_i/X_o)^{0.6}(B_i/B_o)^{0.6}$$

where P is the mean hydraulic depth defined as cross-sectional area divided by top width;
X is the energy term ($S^{1/2}n$);
B is the top width; and
the subscripts "o" and "i" are used for the open water and ice cover cases respectively.

From available field data for the hydrometric site, mean hydraulic depth can be related to gauge height. Thus the above equation can be written as:

$$\frac{f(GH_o)}{f(GH_i)} = (0.759)\left(\frac{X_i}{X_o}\right)^{0.6}\left(\frac{B_i}{B_o}\right)^{0.6}$$

where GH is gauge height and the other symbols are unchanged. From a winter discharge measurement, the winter discharge Q_i can be determined, as well as the flow depth of the ice FD for an actual gauge reading GH_w. The gauge height for ice cover conditions can thus be determined using $GH_i = GH_w - FD$. GH_o can be determined from an open water stage discharge relationship for $Q_o = Q_i$. Knowing values of GH_o and GH_i, B_i and B_o can be readily obtained from cross sections. Therefore, $\left(\frac{X_i}{X_o}\right)^{0.6}$, termed the "winter regime coefficient" can be determined using the above equation. Santeford and Alger (1984) states that the winter regime coefficient is a site specific factor which remains constant throughout the period of solid ice cover (providing control sections remain constant) for a wide range of flows. They also contend that the ratio (B_i/B_o) raised to the 0.6 power will approximate a constant value (for streams of regular cross-section). Therefore;

$$\frac{D_o}{D_i} = \frac{f(GH_o)}{f(GH_i)} = \text{Constant};$$

which can be used to obtain winter discharges using the open water stage-discharge rating curve.

There are several advantages of the Santeford and Alger model over empirical methods of estimating discharge in ice-covered streams. These include:

- a theoretical basis;
- consistency and reproductivity;
- a reduction in wintertime field data collection requirements;
- a reduction in staff time on estimating streamflows; and
- electronic data processing compatibility.

One of these stated advantages requires further commentary. If the Santeford and Alger model is applied, a limited amount of wintertime field data will be necessary to

establish the magnitude of site-specific constants. Once this is done, the above technique should remain valid until such time as there is a major change in the control section (Santeford and Alger, 1984).

A limitation of this modelling approach is that the relationship between stage and channel geometry must remain fixed. However, large accumulations of frazil slush or anchor ice, as often occurs during the early winter period on New Brunswick rivers, changes the relationship.

The type of ice cover, the roughness of the ice, and the roughness of the channel directly impact the magnitude of the winter regime coefficient, as well as indirectly affecting the slope of the energy gradeline (Santeford and Aler, 1984). Therefore, it appears that, for this model to be completely reliable, neither the ice cover conditions nor resistance coefficients of the channel bed or ice cover undersurface should change greatly throughout the winter. The work undertaken along the Nashwaak river and by investigators such as Larsen (1973) demonstrates that this may not be the case.

Recent Developments:

Recent developments include:

(1) a manual is being prepared by Environment Canada in association with the United States Geological Survey on flow measurement under ice cover conditions;
(2) uncertainty analysis of flow measurements under ice cover conditions is planned by Environment Canada; and
(3) a computer model relating winter streamflow to actual flow measurements and temperature, precipitation, snowmelt and hydrograph recession constants is being developed by D. Randall and J.G. Deveau of the Water Resources Branch - Atlantic Region, Environment Canada.

3.6.3 Water Measurement during Breakup

3.6.3.1 Current Status

Due to the considerable difficulty in obtaining reliable discharge measurements without damaging equipment or risking

staff injury or death, flow measurements are generally not obtained during periods of river ice breakup. Discharges have to be estimated for this period.

Except for the moving boat technique which is somewhat risky during the breakup period, field measurements of velocity and discharge are virtually impossible with conventional equipment. However, new technology is being developed which will make such measurements feasible in the future.

3.6.3.2 Water Level Measurements

Water level measurements are easier than velocity measurements to obtain, and there are several manual, analogue and electronic devices which can be used to obtain reliable measurements (refer to Section 3.2).

The problem of water level measurement is often a locational one of selecting sites where readings will be useful for some intended purpose. For example, if it is desired to obtain a peak water level that may occur during an ice jam event, there must be some planning undertaken to ensure that the gauge will be located where there is a good likelihood of backwater due to the formation of a downstream ice jam. However, if it is desired to obtain the peak water level that occurred at a site, regardless of cause, then locating gauges becomes less of a problem.

3.6.3.3 Velocity Measurements

Photogrammetric Methods:

Prowse, Anderson and Smith (1986) reviewed shore-based and aerial survey techniques for measuring surface ice velocities and described the methods and potential problems of estimating river discharge from surface ice velocities. The summary from their paper follows:

> Where observations must be conducted from river banks, trigonometric surveys are the simplest and most direct method for obtaining surface ice velocities. When measurements of instantaneous discharge are required, however, the lengthy time required to complete a full set of cross-sectional surveys reduces the usefulness of the technique, especially on wide

rivers. Instantaneous discharge can best be measured using photographic shore surveys based on a reference grid-image. This approach is also one which could be easily integrated with existing hydrometric station networks to permit automatic recording during the freeze-up and break-up periods. One drawback of the approach for use in low relief areas is the large camera elevations required for wide rivers.

Large format cameras and the associated false-parallax and image-digitizing techniques of photogrammetric analysis form the most sophisticated and accurate methods for determining surface ice velocities. However, given the range of problems and accuracy limitations associated with converting surface ice velocities to discharge values, the accuracy levels of such sophisticated techniques are essentially surplus to the needs of this type of environmental mapping. Images produced by 35 mm photography are fully adequate and offer the opportunity of obtaining more surveys for the same cost. This is especially important considering the need for frequent surveys to define the rapid fluctuations in discharge which occur during the break-up period.

Problems associated with the scale and positioning of 35 mm images can be reduced if the channel bed profile can be accurately located relative to identifiable ground control stations. A minimum of three stations, preferably spaced widely apart, would permit rectification of the image and proper positioning of the shear walls and ice floes. For many locations where this approach could be used, surface maps of sufficient detail already exist. The only step that may be required is to accurately locate the bed profile with respect to the selected ground control stations.

The major problem in deriving discharge from surface ice velocities occurs during the periods of high ice congestion when the friction created by the banks and bed become important. Although K [a coefficient depending upon the vertical velocity distribution] can be reasonably

approximated during periods of low to medium ice concentrations, surface ice velocities cannot be considered representative of surface water velocities above these concentrations.

Index of Surface Velocity Method:

Two non-intrusive sensors coupled together can be used to obtain an index of surface velocity using a signal output correlation technique. The two sensors could be mounted (perhaps underneath a bridge deck) pointing down towards the water surface. The upstream sensor will measure increases in the river surface due to changing water levels or the passage of ice floes. The downstream sensor will measure the same changes a short period later. Knowing the distance between sensors, and the time lapse between the observed signal feature being measured at the upstream and downstream sensors, an approximation of surface velocity can be obtained. From previous studies, the surface velocity can be related to the velocity of the entire flow section. With stage measured, the cross sectional flow area can be estimated from cross section information obtained during open water conditions. Thus, with area and velocity, discharge can be estimated.

There are some limitations to the above method. Firstly, there must be a flow of ice and water. The problem of obtaining a discharge measurement through an ice cover undergoing mature breakup (i.e. "rotting in place") is not solved. Secondly, the sensors must be far enough apart for a noticeable time difference in observing the feature at each sensor yet close enough that transverse flow will not cause the downstream sensor to miss the surface feature.

3.6.3.4 Direct Measurement

At some sites, it may be possible to apply ultrasonic or acoustic flow measurement devices to measure flow during breakup. For discussion on the advantages and disadvantages refer to Section 3.3. Where these sites are suitable for electronic devices they should be given priority consideration for instrumentation.

3.6.4 Estuarial Flow Measurement

3.6.4.1 Benefits and Problems

There are several potential benefits that can be derived from estuarial flow measurement:

1. more direct measurement of total basin flow for streams flowing to the sea;
2. computation of flow and stage at estuarial locations of interest eg. major flood plain locations;
3. better calibration of flood forecast models as the time of travel can be calculated from upper basin stations; and
4. determination of the percentage of flow that can be contributed by ungauged basins.

Estuarial flow measurement is difficult due to tidal effects and salt water intrusion, but new technology and modelling procedures are being developed to handle the situation.

3.6.4.2 New Technology

Magnetic flux meters can be used in tidal estuaries provided that there are not significant density layers due to varying salinity.

Two water level stations can be located along a river reach in order to provide water surface slope. Discharge can then be calculated using estimates of channel cross sectional area, width, flow resistance and water surface slope.

3.6.4.3 Modelling

Modelling can be used to verify and augment estuarial flow measurement. For example, a one-dimensional hydrodynamic computer model has been developed by Environment Canada and successfully applied to several river systems including the Fraser and St. Croix. The model solves transient flow conditions in rivers and tidal estuaries for divided flow or multiple-channel situations where conventional steady-state models can be used (Environment Canada, 1982).

Required input to the model includes:

- tables of hydraulic parameters of cross-sections;
- boundary discharges and/or elevations;
- lateral inflows; and
- information on control structures and log or ice cover (if any).

Principal outputs include:

- elevation and discharge hydrographs at specified locations; and
- profiles at specific times.

The model is based upon the St. Venant equations. It is assumed that the flow is one-dimensional, the pressure is hydrostatic, and that resistance forces described by empirical equations can account for the effects of boundary friction and turbulence. Equations for the conservation of mass and momentum of channel flow are then formulated by considering the motion of a given mass of fluid through a small increment of time in the vicinity of a fixed section.

The river system is represented as a network of river reaches and nodes. Channel network computations are done using a method of superimposition. For any given time step, the solutions for water surface elevation, discharges, and concentrations at mesh points are given by sets of simultaneous linear equations. A set of equations for interior mesh points can be solved assuming that solution values at boundary mesh points are zero. Influence factors due to unit solution values at boundary mesh points are computed at interior mesh points. Boundary conditions are then included and the set of equations for boundary mesh points solved. The boundary solution values are then multiplied by influence factors and added to the values obtained for interior mesh points when boundary mesh points are zero to obtain final solution values at interior mesh points (Environment Canada, 1982).

On the Fraser river, hydrometric and sediment data is important to the assessment of problems and remedial action relating to the maintenance and improvement of a navigation channel. It was deemed essential that river discharges for the tidal estuary be as accurate as those

for non-tidal rivers; i.e. within 5% of rating curve values. The one-dimensional hydrodynamic model was used (Environment Canada, 1983).

The study reach of the lower Fraser river was broken into reaches and nodes. Hydraulic data in the form of time versus stage or discharge hydrographs, rating curves, and structures were used to describe boundary conditions. Input data had to be reliable and reflect as accurately as possible the actual field conditions. For example, the cross-sectional parameters had to be representative of the period being simulated, or remeasured to correct for erosion, deposition or man-made changes.

The one-dimensional hydrodynamic model was successfully applied for computing natural flows in the tidal reach of the Fraser river with an accuracy and frequency such that these flows could be used in calculating suspended sediment loads. The study also revealed that the one-dimensional finite difference model accurately reproduced historic levels and discharges, and provided a technique to fill in missing data for a study area (Environment Canada, 1983).

3.6.4.4 Possible Locations

Possible locations for estuarial flow measurement stations in New Brunswick include, but are not necessarily limited to, those listed in Table 3.3.

(...71)

TABLE 3.3

POSSIBLE ESTUARIAL FLOW MEASUREMENT STATIONS

Location	Possible Benefits	Potential Problem	Other Changes to Exiting Network	Comments
Saint John river at Fredericton	Measurements of stage and flow in major flood prone area (Fredericton).	Vegetation growth may affect ultrasonic signal across river. Discharge station at McKinley Ferry may be discontinued or kept as an upstream station to get river slope.	Water level at Fredericton may be discontinued or made a backup station.	Close to W.S.C. Office. Miminal tidal effect. River ice jams not a problem.
Saint John river at Saint John	Total basin outflow measured. Measurement of stage and flow near a minor flood prone area (Indiantown).	Varying layers of water layers of water density due to presence of salt water may affect signal.	Water level station at Indiantown may be discontinued or kept as a backup station.	Long tidal range. Salt water. Allows for better estimation of flow contributed by upstream ungauged basins.
Miramichi river at Newcastle	Total basin outflow measured. Measurement of stage near a major flood prone area (Newcastle, Chatham Head, Nelson-Miramichi).	Varying density layers due salt water intrusion.	-----	Ice jamming may occur. Navigable Waterway (Newcastle is a port for ocean-going ships). Tidal range smaller than for the Bay of Fundy.

3.6.5 Recommendations

1. The Coordinating Committee (for the N.B. Hydrometric Network) should encourage and support the above mentioned recent modelling and instrumentation developments and, in particular, provide the time and resources necessary for further development of the computer program relating streamflow during the ice cover to hydrograph recession constants and climatic parameters. Such a program could be used to provide a more scientific, less subjective interpretation of discharges under ice and to improve the quality and timeliness of data provided to users.

2. Further research on flow measurement during breakup is recommended. A prototype project using a coupled sensor to obtain surface velocity to use in estimating flow during breakup could be part of this research effort. Possible sites include existing gauged sites such as the Nashwaak River at Durham Bridge and presently ungauged sites such as the Saint John River at Perth-Andover.

3. Models should be developed and applied to the hydrology and hydraulics of an estuarial river reach. These models should be verified and calibrated using a combination of appropriate velocity and stage measurement devices. However, if point flow is sufficient to meet user requirements, then electromagnetic or ultrasonic velocity measurement instrumentation installed to meet specific site considerations may suffice.

4. The Coordinating Committee should establish a Task Force to study the feasibility of establishing (within the next three years) a prototype estuarial flow measurement station along the lower reaches of the Saint John or Miramichi rivers.

4.0 OPERATIONAL ISSUES

4.1 SCOPE

Topics which are primarily operational in nature are discussed in this chapter. These include observers and remote sensing, term stations, frequency of visitation and transboundary interjurisdictional concerns.

4.2 OBSERVERS AND REMOTE SENSING

4.2.1 General

Observers and remote sensing provides alternatives to current trends in hydrometric data acquisition. In order to assess if the trend towards automation is valid, the use of observers and remotely sensed information has to be evaluated.

Observers are those individuals who supplement or support hydrometric data collection activities by the provision of additional services within a defined geographic area. In some cases, additional information is acquired that otherwise would not have been obtained. Observers are usually part-time and often seasonal employees hired as casual staff. Observers may also be employed under contract.

Observers have a bearing on hydrometric data collection as they:

(1) are required for the use of manual instrumentation;
(2) can provide information that existing devices are not established to obtain; and
(3) can improve the reliability of hydrometric instrumentation and reduce the possibility of loss records.

Therefore, the use of observers influence the planning of a hydrometric network as observers affect:

(1) the feasibility of certain types of instrumentation (particularly manual);
(2) the cost of hydrometric network operations; and
(3) the type and amount of data collected.

Remote sensing refers to data collection activities made without direct contact with the object being measured. This could include many different activities, but is often restricted to mean obtaining and using aerial photography and satellite imagery.

Remote sensing techniques can provide greater spatial coverage. It could be used to define an event such as breakup or point source pollution. The resolution currently available or proposed in the future will allow greater use of this type of information particularly in relation to operational planning and event forecasting.

4.2.2 River Observers

The normal duties of a river observer are the:

(1) visual inspection of a predetermined reach of river during periods of ice cover formation, growth, and breakup and during the period of the spring freshet and recording of these observations on a prescribed form; and
(2) telephone notification of flood forecasters when ice jamming or flooding occurs.

Occasional extra duties include assistance in carrying-out surveys of flood conditions.

The advantages and disadvantages of using river observers as listed below.

Advantages

- provides supplementary and background information not available at reasonable costs by other means
- provides information on ice breakup and jamming
- provides information on water levels where the flood occurs (not restricted to the hydrometric reach)
- greater areal coverage than just at a station
- timely information if transmitted by telephone
- "Community presence"

Disadvantages

- administrative problems, time and costs especially if there is inconsistent hiring and training of individuals
- often poorly defined information requirements
- costs for travel, meals, salary and employee benefits

- problems with safety during flood season and when winter travel required
- training often non-uniform
- information gathered is more project-oriented than hydrometric network oriented; should be taken into account in project estimates
- travel could be prevented by flooding
- new technology in remote sensing may eventually replace
- potential reliability problem.

4.2.3 Station Attendants

Normal duties of station attendants are:

(1) reporting, on a prescribed card, the physical condition of the building and instrumentation, operating status of station equipment, and stream conditions at a particular date and time; and
(2) providing notification of station malfunctions by telephone.

Occasional or contingent duties include:

(1) minor repairs to equipment or emergency removal of equipment;
(2) repairs to gauge shelter caused by vandalism or storm damage;
(3) supply of real-time information on stream conditions upon demand; and
(4) provision of water level readings when instrumentation not reliable.

Prior to the introduction of automatic water level recording gauges during the early '50's, it was necessary to employ gauge readers to obtain daily water level readings at most gauging stations in New Brunswick. The practice of hiring gauge readers continued until 1978, regardless of whether the station was equipped with a manual or automatic gauge. Gauge readers were often the family of the property owner and the job of gauge attendant was sometimes an incentive to obtain permission to construct a gauge on that person's land. At that time, 65 gauging stations were serviced by attendants.

Early in 1978, it was decided to dismiss all attendants except those in the following categories:

(1) attendants at international stations;
(2) attendants involved with sediment sampling;
(3) attendants paid by other agencies;
(4) attendants employed at "typical" stations where chart removal and transmittal was required on a monthly basis to complete Form D information; and
(5) attendants who were also property owners where the gauge was located.

The above action was carried out as a cost saving measure and resulted in the immediate dismissal of 34 attendants.

It was also decided at that time not to hire any more gauge readers unless they fall into the categories 1 to 4 above. Since that time, the number of gauge readers has fallen to nine.

Station attendants have an effect on a hydrometric data collection program. Some advantages and disadvantages of employing station attendants are as listed below.

Advantages

- second person at site for additional safety and general assistance
- equipment malfunction notification
- provides river information not covered by present data acquisition/telemetry devices
- can provide useful breakup information
- direct community notification and linkage
- less vandalism due to local inspection and presence
- property rights often easier to obtain at low rates
- local labor for short term tasks
- exterior fixed asset maintenance (painting, grounds keeping)
- occasional saving of equipment or temporary repairs
- some current instrumentation requires them

Disadvantages

- operating costs
- administrative costs including overhead and vacation pay

- sometimes station attendants are unreliable or unavailable
- indirect supervision and control due to distance from office
- information provided has to be interpreted and checked
- information subjective and non-uniform
- updating and training visits required
- safety a concern for untrained or poorly trained personnel; safety equipment may have to be supplied
- restrictions on hiring (minimum hourly wage, age limit)
- time synchronized data hard to obtain
- limited to time frames, or time intervals, prescribed somewhat by the observers

4.2.4 Local Observers

Normal duties of a local observer would include:

(1) visual inspection of a short reach of river during ice breakup and high flow periods; and
(2) marking of high water levels during flood events or reading of staff or crest gauges.

Occasional extra duties may include assistance with field surveys in that area as required.

Local observers are essential where manual water level gauges exist. Local observers are often paid on a per-reading basis (usually between $1.00 and $2.00 per reading) with a minimum number of readings guaranteed. Readers of manual instrumentation can sometimes be volunteers, but it is increasingly difficult to find reliable people who will commit themselves to a long-term program of daily (or more frequent) readings.

The use of local observers has the following advantages and disadvantages:

Advantages

- provides supplementary or background information otherwise not available at a reasonable cost
- can be used as supplementary labor
- cheaper than river observers
- "ground-truthing" for remote sensing operations can be provided
- "community presence"

Disadvantages

- administrative costs in hiring, training, overhead
- sole function restricted to primary agency concern or specific purposes
- hard to mesh qualitative information with quantitative data
- operational planning required
- sometimes unreliable or unavailable
- subjective and nonuniform information provided
- site-specific information provided

4.2.5 Remote Sensing

Remote sensing is the study of the earth (and its atmosphere) by the interpretation and analysis of electromagnetic radiation reflected and emitted by the earth.

Three broad categories of remote sensing imagery utilization have been recognized:

(1) simple qualitative observations (eg. differences in the tone or hue of water bodies which indicate a difference in water quality, sediment loading or depth);
(2) analysis of the size, pattern, location or distribution of a phenomenon (eg. quantitative analysis of a drainage basin); and
(3) correlation of remotely sensed properties such as reflectance and remittance levels with ground point measurement (Williams, 1986).

In hydrology, an earth science, remote sensing can be useful in the study of spatial changes in a hydrologic phenomenon, and thus has an advantage over conventional hydrometric measurements specific to one location.

The role of remote sensing in hydrology has grown rapidly during the past decade and is becoming increasingly important to both the planning and operational aspects of hydrology. The appearance of the term "satellite hydrology" exemplifies the rapid development in this field. The utilization of remote sensing in hydrology is expected to increase with improvement in the quality, type and availability of the imagery; with better training

of hydrologists to interpret and analyse imagery; and with technological advances in satellite technology and imagery receipt and processing.

Remote sensing can be used in hydrology to:

(1) describe the physical features of a water body;
(2) measure or estimate several components of the hydrologic cycle including precipitation, evapotranspiration, and soil moisture; and to
(3) document an event such as an oil spill or flood.

Satellite systems currently in use include the American LANDSAT and French SPOT, as well as various N.O.A.A. series and T.I.R.O.S. series meteorological satellites.

The Landsat satellites follow a polar orbit which takes them over the same spot on the earth every 16 days. Each Landsat spacecraft has a multispectral scanner (M.S.S.) which has a spatial resolution of 80 metres and senses in four spectral bands. The latest (Landsat 5) carries an M.S.S. and thematic mapping sensor which has a spatial resolution of 30 metres and seven spectral bands (Office of Technology Assessment, 1985).

The two SPOT satellites follow a 26 day cycle circular orbit providing global coverage. They carry high resolution electronic scanners with a 60 km swath width and a sampling interval (pixel size) of 10 m in the panchromatic mode and 20 m in the multispectral mode (Bracht, 1983). A particular feature of the SPOT system is the capability to request data acquisition.

Proposed satellite systems include the Canadian RADARSAT. This polar-orbiting satellite will have a sun synchronous orbit, at an altitude of 1001 km, with a 16 day cycle. The primary sensor will be S.A.R. (synthetic aperture radar), but a visual light sensor and other sensors will also be included. S.A.R. imagery is expected to be of value in flood mapping and soil moisture studies, and possibly in the monitoring of snow cover (Goodison, Langham and Athanassiadis, 1983).

Recognizing the potential of enhanced hydrologic forecasting using remotely sensed data, Environment Canada hired a consultant to study the technical merits and economic advantages of remote sensing. The objectives were to modify conventional methodologies of short term and

long-term streamflow forecasting by incorporating the use of data acquired via contemporary remote sensing technologies and apply these technologies to a Canadian basin (A.J. Robinson & Associates Inc., 1986).

The consultant identified two potential advantages to using remotely sensed data as an integral part of a hydrological forecasting model:

(1) to improve the accuracy of existing modelling; and
(2) to obtain the same degree of modelling accuracy at lower cost.

Also, the consultant grouped various hydrologic models as to their suitability for using remotely-sensed data.

The advantages and disadvantages of remote sensing include the following.

Advantages

- great areal coverage
- more quantitative information compared to that provided by observers
- readily accessible by modern technological means
- readily incorporated in software forecasting models
- good definition of areal coverage of event
- can be used for many hydrometric/hydrologic data collection purposes (such as soil moisture detection) to increase accuracy of peak flow prediction
- can be used to detect ice formation, cover extent and breakup

Disadvantages

- no real-time information as could be provided by an observer
- affected by weather conditions
- coverage not guaranteed for an event
- requires computer hardware (getting cheaper)
- requires trained users
- requires ground truthing; maybe by local observers
- stage cannot be obtained as precisely as can be by an observer

4.2.6 Recommendations

(1) The status quo with respect to gauge attendants should be maintained for the next five years. At present, most gauge attendants are the owners, or relatives of owners, of land on which a gauge is located. For the regular hydrometric network, the trend is towards real-time data collection with data collection platforms or telemarks, thus eliminating the need for gauge attendants in most cases. However, a need for gauge attendants will remain in the next five years at short term stations with manual observation equipment (for example, seasonal or event stations).

(2) River observers should be hired to fulfill special requirements for information along a river reach. When river observers are needed to collect information on river ice conditions, they should be employed for the entire period from freeze-up to breakup. Possible locations for river observers in New Brunswick include, but are not necessarily limited to, the Saint John river, Meduxnekeag river, Nashwaak river, Kennebecasis river, and Restigouche river which are prone to ice-related problems.

(3) River observers should be an established component of the hydrometric program; however, they pose an administrative problem. Funding arrangements should be defined by the needs of supporting agencies. Detailed work descriptions should be prepared for regular part-time or seasonal positions for which a budget allocation has been made.

(4) Municipalities with flood prone areas or research agencies with special projects should be encouraged to provide and supervise local observers at their own expense.

(5) Work be done to integrate access to environmental data bases including those containing remotely sensed data. This enhanced access capability will ensure the future use of remotely sensed data and could eliminate the need for observers.

4.3 TERM STATIONS

4.3.1 Types of Stations by Purpose

Types of term stations are:

A. PROJECT STATIONS

Project stations may include stations established in order to improve data transfer models. Conventional equipment is often used. A project station is a hydrometric station established for a time frame defined by project requirements before implementation, and with equipment and manpower tailored to user requirements.

B. SEASONAL OR FLOW CONDITION STATIONS

Seasonal or flow condition hydrometric or water level stations are established for continuous or point measurements during a relatively short period of time. These stations are highly project oriented. Different instrumentation may be used for different applications.

C. EVENT STATIONS

The equipment at an event station is tailored to monitor a particular short duration event, eg. an oil spill. Intermittent point measurements are usually obtained. User needs often define equipment requirements.

4.3.2 Project Stations

From an operational standpoint, a five year period is generally required to establish a rating which could be used to define flow events to reasonable limits of accuracy providing that the station exhibits stable control. Project stations should be operated for the duration of the project or until the hydrologic regime has been adequately defined.

The disadvantages of using conventional instrumentation for project stations arises from the lower limit to the number of years of station operation required for representative data to be derived. The operational cost per station using conventional equipment is high.

The installation of project-oriented term stations for the development and calibration of data transfer models is limited by the operational constraints of staff time and budget allocation. Conventional instrumentation requires additional staff in order to effectively calibrate the sites within the allowable time frame.

Short term stations will become more feasible when new data sensing, acquisition and monitoring equipment is developed such that stations become more portable and easier to install and retrieve. If these stations are automated, greater use can be made of short term stations as there will be less impact on existing staff. Short term stations will be more feasible if they can operate without much attention and if application of instrumentation is as flexible as possible. Fully automated data acquisition should be further reviewed with respect to term stations as they have the chance of increasing the feasibility of term stations.

4.3.3 Seasonal or Flow Condition Stations

4.3.3.1 Purpose, Advantages and Disadvantages

The same instrumentation may be used at seasonal or flow condition stations as at project stations or long term stations. However less expensive instrumentation (as staff boards, chain gauges) may also be used.

Seasonal stations may be established to:

(1) replace a need for a year-round hydrometric station if interested in only one flow period; and/or
(2) fulfill a seasonal need for hydrometric data.

The former is the more difficult. It is generally only feasible if the streamflow event or period of interest (usually high or low flows) regularly occurs during the same season each year. The advantages of seasonal stations, in general, are:

- a potential for lower operating costs under current conventional operating procedures;
- a possibility of sharing instrumentation between automated stations if stations are operated for different flow events or periods; and

- the opportunity to operate more stations with the same staff resources (providing that the stations do not have manual instrumentation).

The disadvantages of seasonal stations are:

- a good possibility of missing an extreme event;
- a requirement for more time specific monitoring in order to develop rating curves (depending upon type of instrumentation used);
- high initial start-up costs per unit output (i.e. the cost of site surveying and shelter construction etc. may be as high as for a year-round station but less streamflow data are obtained);
- a requirement for more site planning and careful setup in order to obtain accurate measurements during the seasonal flow period;
- high manpower requirements per unit output (i.e. seasonal stations are more manpower intensive relative to the amount of streamflow record obtained than year round stations);
- possible administrative difficulties in staff scheduling, cost allocation, and cost sharing negotiations; and
- a disruption of normal operating procedures.

4.3.3.2 Seasonal High Flow Stations

The proportion of annual maximum peak floods occurring in a three month period (March, April, May) each year is greatest in northern New Brunswick as shown on Plate 13 titled "Annual Maximum Floods Occurring in the March, April, May Period" of the report titled Regional Flood Frequency Analyses (Acres Consulting Services Limited, 1977). Figure 4.1 adapted from Plate 13 of the above report indicates where in New Brunswick it will or will not be feasible to operate a seasonal high flow station assuming that it is desirable not to miss more than one in ten annual maximum flood peaks and that it is unacceptable to miss more than four flood peaks.

Various options exist with regard to instrumentation for a high flow seasonal station. These are:

(1) manual instrumentation;
(2) analog continuous recording devices;
(3) one parameter (stage) electronic devices; and
(4) three parameter (stage, velocity, flow) electronic devices.

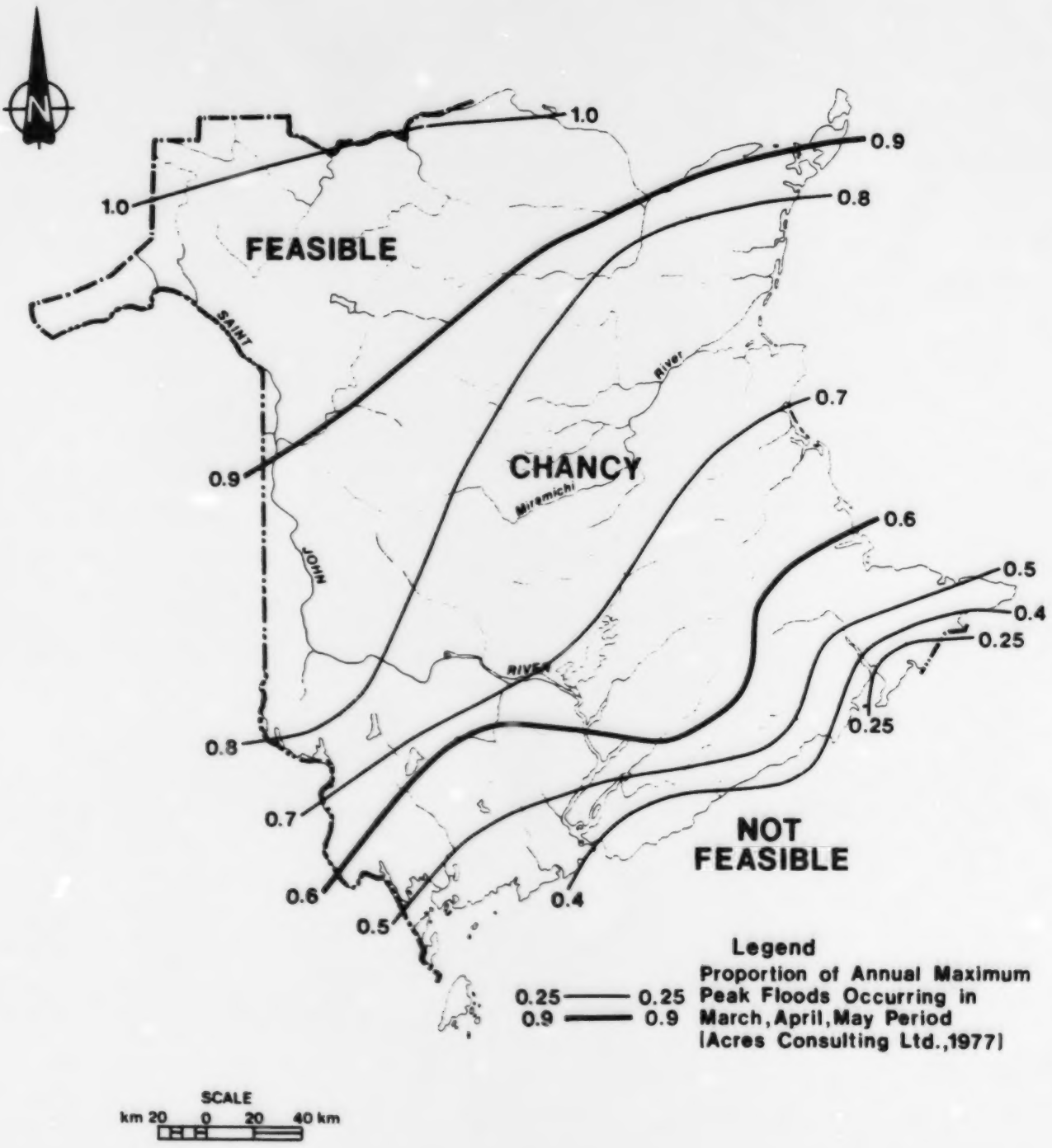

Figure 4.1 Hydrologic Feasibility of Seasonal High Flow Stations

Manual Instrumentation:

From a network standpoint, the advantage of using manual instrumentation for monitoring high flow periods is that savings in instrumentation cost may allow for greater spatial coverage which may reduce data transfer modelling error. This assumes that sufficient manpower will be available to maintain station ratings. This advantage may be lost if data handling procedures are not compatible with this method of data acquisition (as is the case now).

The disadvantages of using manual instrumentation for obtaining seasonal records during high flow periods includes:

- the lack of instantaneous flow values and hourly discharges;
- the impossibility of verifying reading accuracy;
- the difficulty in incorporating the manual readings in the office procedure;
- the inapplicability of the data to real-time operational needs;
- the requirement for more checking of data by regular staff;
- high communication costs; and
- an increase in overall operating costs.

With manual instrumentation, it is difficult to maintain data quality. There is a greater possibility (than for continuous recording devices) of lost record as the gauge attendant may be ill or on vacation. It is difficult to get the number of readings per day required to determine daily discharge during high flow periods or to obtain time-synchronized data from a number of gauging sites. The accuracy of readings obtained manually are non-verifiable. All this leads to a lower perception of data quality among users.

For further discussion of some of the advantages and disadvantages of manual instrumentation, please refer to Subsection 4.2.3 (Station Attendants) and Subsection 3.2.2 (Manual Water Level Instrumentation).

Analogue Continuous Recording Devices:

The use of conventional float-actuated devices (refer to Subsection 3.2.3) or pressure-actuated devices (refer to Subsection 3.2.4) with continuous analogue recorders for seasonal flow measurement during high flow periods is compatible with present-day data handling procedures. It is also possible to obtain near-real time data if telemetry is used. However, such devices are more expensive and less transferable than manual instrumentation and thus the possibility of greater spatial coverage (due to the operation of seasonal stations) is somewhat reduced. There may be some saving in annual operating costs if such a conventional station is operated seasonally.

The disadvantages of using conventional float or pressure-actuated devices with continuous analogue recorders for seasonal flow measurement includes:

- the need for additional trips to ensure that the station is operational prior to the high flow season;
- the requirement for additional monitoring (perhaps by a gauge attendant) unless telemetry is applied; and
- the high capital costs per unit output (i.e. stations are as expensive to set-up as year-round stations yet only seasonal data obtained).

A requirement for real-time (or near real-time) data reduces the possible savings due to seasonal operation of a hydrometric station. Equipping a station with telemetry will increase the overall instrumentation cost and thus the capital costs per unit output. Also, there will be added cost due to the administrative work required to arrange for real-time (or near real-time) data collection on a seasonal basis (for example, arranging seasonal data slot allocations with NESDIS for data collection platforms or arranging connection or disconnection of telephone service for a telemark).

Data accuracy may be affected by operating on a seasonal basis. If the station is operated only during the high flow period, then the low water portion of the stage-discharge relationship useful in defining the rate of rise of the rating curve is not obtained. This greatly affects the high water extension of the rating curve thus increasing inaccuracies in the upper curve.

A channel may be very unstable during a flood event with erosion on the rising limb and deposition on the falling limb of the hydrograph. Therefore, it may be necessary to check the stage-discharge relationship after the flood season. This may involve a field trip during a lower water period outside of the intended season of streamflow measurement in order to do levelling work if it appears that the channel cross section has changed greatly. This can be somewhat overcome by good site selection.

It is also desirable to have a winter discharge measurement at the start of the season. This is especially true during ice cover periods when discharges have to be interpolated between measured values by considering climate or other measured streamflows in the region. There may be a logistics and manpower problem created if a large number of seasonal stations are to become operational within a couple of weeks at the beginning of a high flow period.

One Parameter (Stage) Electronic Devices

With respect to seasonal stations to obtain measurements during high flow periods, a digital electronic system, consisting of a transducer coupled to data acquisition instrumentation, has several advantages over analog devices. Firstly, it is less expensive (refer to Section 3.3). Secondly, installation costs are less and they are easier to install and maintain. Therefore, there is greater feasibility in sharing instrumentation at different sites for different periods or flow conditions. Thirdly, the need for digitizing is eliminated. The data is compatible with telemetry and electronic data processing.

The major disadvantages is its comparably high cost per unit output and the requirement for a field computer for the site verification of data.

The accuracy depends upon the range of the device. The higher the range the lower the accuracy due to the analog to digital conversion (12 bits or greater is recommended). The accuracy also depends upon the selected sampling frequency.

Three Parameter (Stage, Velocity, Slope) Sensing Procedure

The problem with rating curve extension for high flow periods at a seasonal station where measurements are obtained only during high flow periods can be overcome by sensing three flow-related parameters (stage, velocity and slope). These three parameters define the flow event and provide sufficient redundancy to check the output. Electronic instrumentation permits this type of sensing procedure.

The principal advantage is that there is no developmental period required for the stage-discharge relationship. There is no metering requirement. This means that the data can be used as soon as the station is deemed fully operational. This is especially useful when seasonal records are being obtained.

Other advantages include:

(1) elimination of the need for digitizing;
(2) high compatibility with real-time data requirements;
(3) high compatibility with automatic data handling and processing procedures; and
(4) transportability between hydrometric sites.

The principal disadvantage is the high initial costs of instrumentation. For example, the cost of installing a fixed magnetic flux flow measurement device will probably exceed $50,000.

Site selection is critical so time and effort must be spent on it. This applies to seasonal stations as well as year-round stations.

Accuracy depends upon:

(1) selected sampling frequency;
(2) the range (as velocity is inversely proportional to the range); and
(3) water quality under certain circumstances.

Digital data handling procedures are highly compatible with uncertainty analysis through the application of real-time models and eliminates the need for digitizing charts which may be a source of error.

The overall sampling error is less than for analog or manual devices.

4.3.3.3 Seasonal Low Flow Stations

The demand for low flow information is increasing and there is now a more varied user group wanting low flow information compared to those requiring high flow data. Low flow information is useful in planning water supplies or undertaking environmental studies (eg. determining the assimilative capacity of a stream). It is also of interest to agencies involved with environmental monitoring, aquaculture, angling, commercial fisheries, and protection of the aquatic environment. Boaters often request water level and/or flow data during the summer months.

The installation and operation of seasonal stations to collect low flow information may fulfill some of the need for low flow information. In particular, seasonal stations may provide all the low flow data required for seasonal activities such as agriculture (cultivation) or boating. However, there is a chance of missing an annual extreme lowflow which may occur in different seasons in different years at the same site. This may limit the usefulness of collected data for other purposes such as drought frequency analysis of a potential year-round water supply.

Seasonal low flow measurements may also be useful in understanding the hydrologic regime prior to the establishment of a regular hydrometric station. Where feasible, this will allow extreme low flow events to be more readily defined as the low flow frequency curve is asymptotic beyond the 10 year return period.

Generally, low flows tend to occur more seasonally on streams in southern New Brunswick. For example, 21 out of 23 annual minimum daily discharges for the Petitcodiac River Near Petitcodiac (Station No. 01BO002) occurred during the months of August, September and October. In contrast, annual minimum daily discharges for the Restigouche River Below Kedgwick River (Station No. 01BC001) measured during a 22 year period occurred during eight different months.

Figure 4.2 depicts the portions of the Province where seasonal low flow stations for other than strictly seasonal purposes may be or may not be feasible.

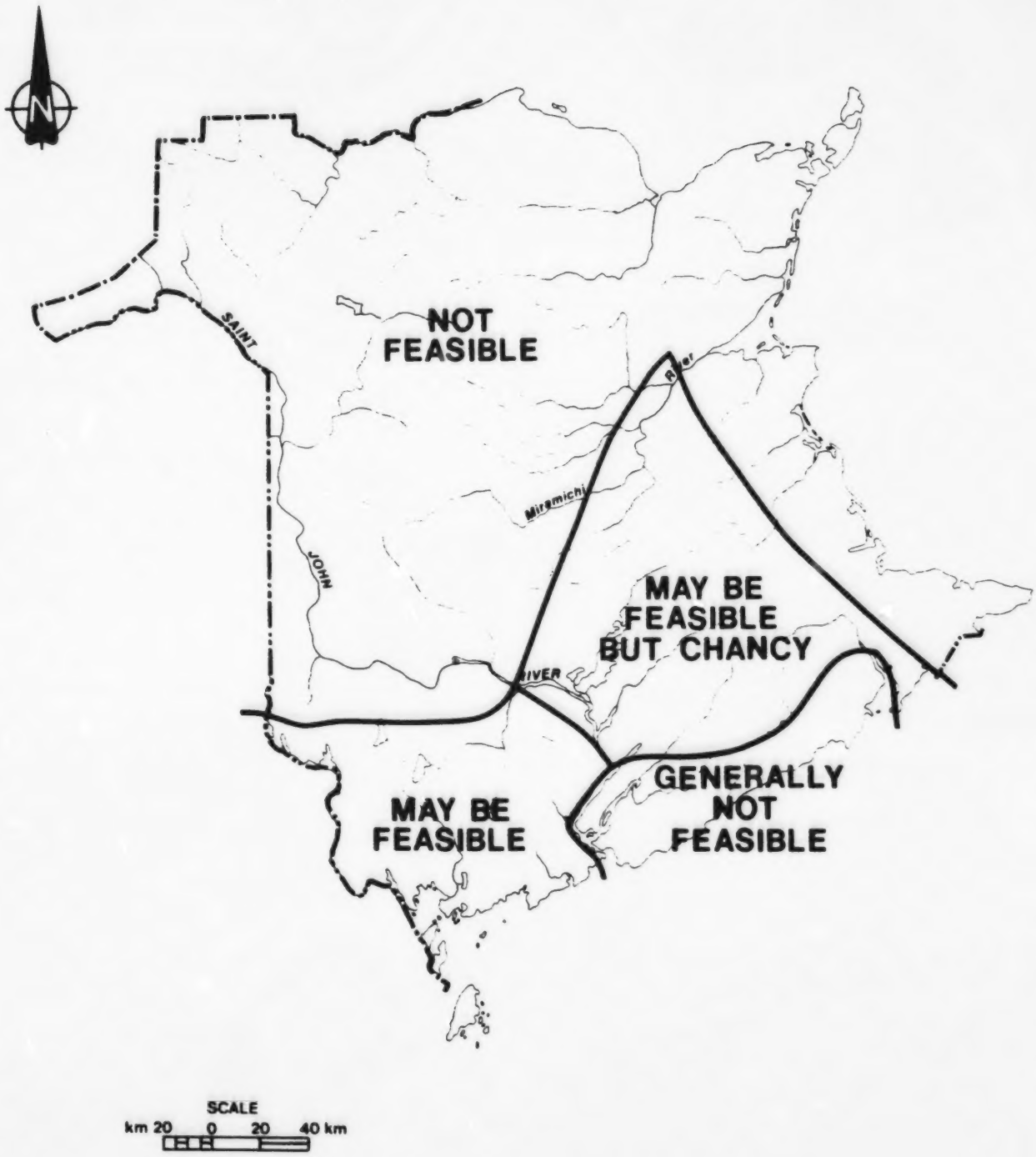

Figure 4.2 Hydrologic Feasibility of Seasonal Low Flow Stations

Low flows are easier to measure manually. There is little change in stage during a low flow period so less frequent measurements are required. However, the measurement of stage must be more accurate than for high flow periods if reasonable flows are to be determined. Some advantages and disadvantages of manual stage measurement are provided in Subsection 3.2.2 (Manual Water Level Observation).

Hydrometric site selection is more critical than during higher flows. The gauge must be set so that measurements can be obtained in a portion of the channel that will not go dry during a low flow period. The accuracy of certain electronic velocity measurement devices may be affected by aquatic vegetation or higher concentrations of contaminants during periods of low flow. In addition, exposure of instrumentation during low water periods may make them more prone to vandalism.

Many of the operational concerns in operating a seasonal high flow measurement station also apply to a seasonal low flow station.

4.3.3.4 Seasonal Water Level Stations

Seasonal water level stations may be feasible when water levels are needed for seasonal uses such as navigation and flood forecasting. For example, Jemseg River at Jemseg (Station Number 01AD004) provides water level information used primarily during the spring for flood forecasting purposes. Closure of this station during the remainder of the year will reduce operational costs associated with field visits. In addition, its instrumentation may then be shared with stations operated during other seasons. However, the costs associated with station reactivation or instrumentation relocation will have to be considered. For this reason, savings in operational costs will not be directly proportional to the percentage of the year the station is not operating.

4.3.4 Event Stations

Manual or highly portable devices for fast data measurement are needed. The user requirements and event characteristics define equipment requirements.

Table 4.1 identifies some methods that may be suitable for the monitoring and observation of different types of events. However, in a specific case, the characteristics of the event and the site may prohibit or limit the use of a method.

4.3.5 Recommendations

(1) Except for seasonal or event stations, all conventional standard hydrometric stations should be operated for the period of time required to define the hydrologic regime. Based upon past experience, a statistical guideline is that a station should be operated a minimum of five years so that there is a reasonable degree of success of obtaining good quality data at a site. This will ensure that data acquired are of value for use in frequency analyses and data transfer models.

(2) Based upon past experience, term stations should not be implemented unless due consideration is given to the capital and operating costs of term stations. Additional staff resources should be identified during the planning of term stations. If you are going to do it, do it right.

4.4 FREQUENCY OF VISITATION

4.4.1 Need for Visitation

Hydrometric sites are visited in order to:

(1) undertake streamflow measurements in order to establish or verify a stage-discharge relationship (rating curve) during open water periods;
(2) obtain discharge measurements to be used in the interpolation of streamflow between consecutive measurements during winter periods;
(3) obtain hydrometric station charts;
(4) check operation of equipment;
(5) maintain and repair equipment and shelter; and/or
(6) install new instrumentation.

The frequency of visitation must be adequate to ensure that the instrumentation is providing sufficient hydrometric information for the intended purpose. The factor limiting the length of time between visits is the

TABLE 4.1

METHODS OF EVENT MEASUREMENT AND OBSERVATION

Method	Instrumentation	Personnel	Cost Range	Lead Time Required	Data Quality	Constraints	SUITABILITY FOR EVENT: Water Withdrawals Regulation	Floods	Flash Floods	Ice Jams	Toxic Spills	Drought
Direct readings of stage	levelling equip.	surveyor & rodman	medium	usually 1 day	Precise Accurate Non-continuous	Daylight hrs. only Accessibility	X	X		X	X	X
Direct readings of flow	levelling equip. stream gauge equip.	hydrometric technician(s)	medium	usually 1 day	Good	Daylight hrs. only Accessibility	X				L	X
Setting water level marks	tools	non-technical	low	approx. 3 hrs.	Variable Unquantifiable	Availability of people Accessibility Requires follow-up levelling		X	X	X	S	
Photography	suitable camera	non-technical	low	approx. 3 hrs.	Dependable upon documentation and visible reference points	Daylight hrs. only Accessibility Vantage points		X	X	X	X	L
Manual instrumentation	staff gauge	non-technical	low	usually 2 days	Good Depends upon frequency of readings	Site selection important Proximity of gauge reader	X	X		L	X	X
	crest gauge	non-technical	medium	usually 2 days	Variable Unverifiable One one value Not time-related	Site selection important Limited range Requires follow-up levelling		X	L			
	wire weight	non-technical	medium	usually 2 days	Good Usefulness depends upon frequency of readings	Site selection important Proximity of gauge reader Daylight hrs. only	X	X	L	S	X	X

TABLE 4.1 CONTINUED:-

METHODS OF EVENT MEASUREMENT AND OBSERVATION CONTINUED:-

Method	Instrumentation	Personnel	Cost Range	Lead Time Required	Water Data Quality	Constraints	SUITABILITY FOR EVENT: Withdrawals Regulation	Floods	Flash Floods	Ice Jams	Toxic Spills	Drought
Pressure-activated continuous recorders	servo-manometer or Winnipeg	technical	high	usually 1-2 days	Very good (good Winnipeg)	Shelter required Need for careful orifice placement	X	X				
Float-activated contiuous recorders	stilling well A3J & A71	technical	high	usually 1-4 weeks	Excellent	Difficult & costly to install Site constraints	X					X
Electronic devices		technical	high	not yet available	Very good		X	X				X
Remote sensing		technical	high	a day or more for administrative arrangements	Good spatial coverage Resolution improving	Present resolution limited	S	X			X	

Notes:

(1) Symbols: X - Suitable for event
L - Limited use
S - Seldom applicable or useable

(2) This table is a general guide only. A method of event measurement and observation may or may not be feasible or suitable for a particular event.

(3) This table refers to the instrumentation that may be chosen to monitor an event. Already existing stations with alternate equipment may also be used for event monitoring.

acceptable risk of failure. The acceptable risk of failure may vary from station to station and from season to season. For example a station used for flood forecasting has a low acceptable risk of failure, especially during the spring freshet period. Such a station can be considered a critical use station.

A critical use station is any station whose records/measurements are used for purposes which affect human health or safety (including water supplies) or for stations the accurate data of which are deemed necessary for navigation or legal purposes. The acceptable period between visits to these critical use stations will be shorter than at other stations.

The frequency of visitation also depends upon the capability and reliability of the instrumentation (including telemetry). For example, stations with servo-manometers are more prone to failure than stations with stilling wells. All other factors being equal, stations with servo-manometers will thus require more site visits than stations with stilling wells.

The frequency of visitation also depends upon the stability of the hydrometric reach. Sufficient site visits are required to ensure that the stage-discharge relationship has not changed.

Field survey circuits, comprising visits to two or more hydrometric sites, must be designed to be effective and time efficient. However, the human factor (including the age, physical condition and training of staff) must be considered in circuit design and site visitation planning.

4.4.2 Visitation and Loss of Record

In New Brunswick, over 80% of the regular hydrometric stations are visited between 12 and 14 times per year. The targeted minimum number of stations visits per year is 11. The loss stage record is approximately 5%. However, discharges are usually estimated for periods of lost records and thus appears in the publications. Missing water level records are usually not estimated.

An analysis of stage records in Kansas, U.S.A. indicates a gradual increase in lost records during an eleven year period primarily because of a reduction in the

frequency of station visits and an increase in the number of less-experienced technicians (Livingston, 1983). Figure 4.3 (taken from the Kansas study) shows a relationship between the number of annual visits and the average number of days of total lost record during the year. (The figure also shows that stations with graphic recorders had as much as 30% less lost record than stations with digital recorders).

The failure characteristics of five river flow gauging stations from a United States Geological Survey (U.S.G.S.) district were examined. It was determined that failures seem to occur randomly (Poisson distribution) and that the time to failure was exponentially distributed (Kitanidis, Lara and Lane, 1984). A maximum likelihood method of estimating the average time to failure from available data was proposed and analysed.

A probabilistic model of the process of gauging-station failures was developed, calibrated and validated. This model can be used to derive the distributions of the number of failures and the length of missing records. It can also be used, through simulation, to determine the accuracy of daily or monthly streamflow values.

4.4.3 Recommendations

(1) The U.S.G.S. computer program called the Travelling Hydrographer which assesses the probability of instrumentation failure should be applied to the N.B. hydrometric network to determine the optimum frequency of visitation. However, the results should be interpreted in terms of data accuracy requirements and other operational constraints (e.g. staff resources).

(2) Satellite data collection platforms should be established at any critical use station within a normal field survey circuit. A normal field survey circuit consists of those stations within a geographical area which are conveniently grouped for visitation. Within the circuit, there may be stations deemed critical for some purpose (e.g. flood forecasting). At such stations, satellite data collection platforms should be installed so that station operations can be closely monitored and emergency repairs carried out if necessary.

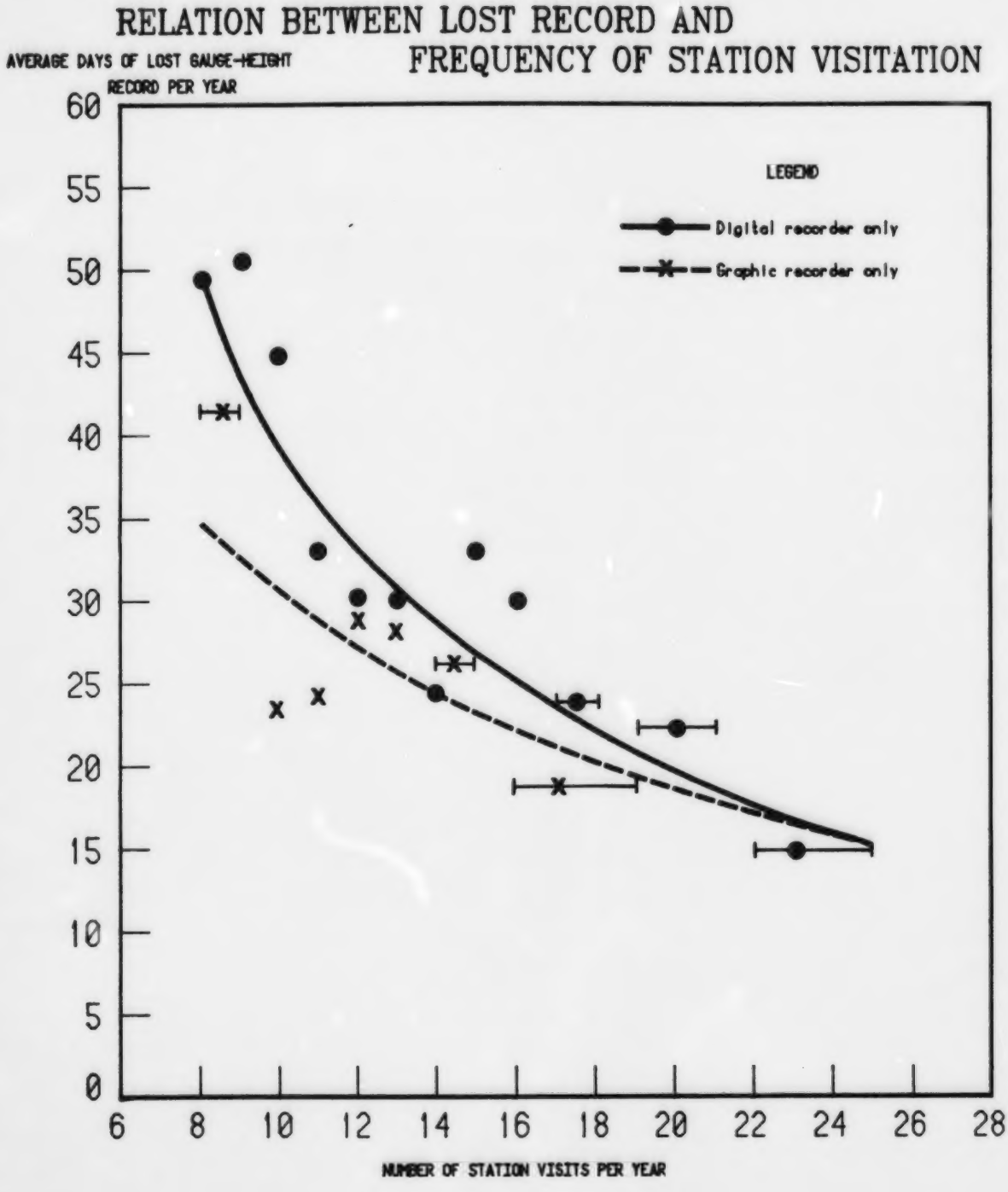

Figure 4.3 Relation between Lost Record and Frequency of Station Visitations

(3) The network operator (the Water Resources Branch of Environment Canada) should develop standard procedures to determine optimum field circuits for hydrometric activities. These procedures should include such considerations as data accuracy requirements, travel costs and human factors (e.g. the age, physical condition and training of staff).

(4) Operational procedures must be reviewed periodically as automatic data acquisition becomes a substantial portion of the network. Once data acquisition is more automated, the emphasis of staff activity should be towards increased data analysis and interpretation to futher improve the effectiveness of the network and the usefulness of the data to the user.

4.5 INTER-JURISDICTIONAL TRANS-BOUNDARY CONCERNS

4.5.1 International River Basins (United States and Canada)

- Saint John River Basin incl. the following rivers which cross or flow along the international border: Saint John river, the Aroostook river, the Big Presquile stream and the Meduxnekeag river.
- St. Croix River Basin

4.5.2 Interprovincial River Basins (Quebec and New Brunswick)

- Restigouche River Basin
- Saint John River Basin incl. the following rivers which cross or flow along the provincial border: the St. Francis river, Baker brook, and Madawaska river.

4.5.3 Interprovincial River Basins (Nova Scotia and New Brunswick)

- Missiguash River Basin
- Tidnish River Basin

These rivers on the Isthmus of Chignecto connecting N.B. and N.S. are small and not considered to be of major importance.

4.5.4 Concerns

International basins:

- The Water Survey of Canada now operate stations on both sides of the international border. Operational concerns include duty on equipment, vehicle insurance for travel outside of Canada, maintenance of existing sites and compliance with American regulations.

- Instrumentation development and use differs. For example, the data collection platforms used by agencies on both sides of the border are not compatible regarding programming. The U.S.G.S. cannot always respond to emergency repairs of data collection platforms used for flood forecasting.

- Different water years are used. The Americans use a water year ending in October while Canadians use the calendar year.

- Different units of measurement are used. The Americans use the Imperial system of units while the Canadians use the SI (metric) system.

Interprovincial basins:

- Most interprovincial rivers flow into New Brunswick. Upstream development is sparse. Therefore, there is little reason for upstream jurisdictions to collect information on these streams.

- An operating protocol has to be established.

4.5.5 Recommendations

(1) It is becoming increasing evident that development in American and Canadian instrumentation and field equipment are following diverging paths. Since future equipment development programs must be compatible with our data handling systems, and it is foreseen that this technical problem cannot be readily overcome, it is necessary that data at selected sites in Maine be collected using instrumentation suitable for our purposes. Therefore, it is recommended that any equipment or instrumentation necessary for flood forecasting or near real-time use be operated on both sides of the international

border by a Canadian agency (such as the Water Survey of Canada) or under formal Agreement with the United States Geological Survey (or their equivalent) for emergency repairs and maintenance of equipment. A similar situation may arise with the Province of Quebec.

(2) Close cooperation and contact with American hydrometric data collection agencies, in particular the United States Geological Survey, should be maintained.

(3) Mutual sharing of hydrometric data through direct computer-to-computer communications should be explored by the respective agencies on both sides of the border.

(4) If jurisdictional problems ever arise between American and Canadian agencies regarding the operation of stations in the State of Maine, consideration should be given to the installation of additional Water Survey of Canada operated stations along the upstream tributaries of the Saint John river in the Province of Quebec.

(5) The Coordinating Committee should formally request the International Affairs section of Environment Canada to facilitate transfer of data collection equipment across the international border. Arrangements can possibly be made with Customs and Excise Canada and American authorities to allow for instrumentation and equipment to be freely shipped across the border. This would legalize current practice.

5.0 PERSPECTIVES ON FUTURE NETWORKS

5.1 THE NETWORK IN THE YEAR 1992

The characteristics of the New Brunswick hydrometric network of 1992 will reflect the results of action already underway. These actions are to automate data acquisition activities and to integrate hydrometric data acquisition with other environmental monitoring activities, predominantly those data collection and integration activities which include data pertaining to water quality and the atmospheric environment.

These actions are dictated by the need to:

(a) provide users with data in real-time;

Increasingly, water resource managers are requesting data in real-time to reflect the timeframe in which decisions must be made. Currently, this need is predominant to the flood forecasting, navigation and reservoir operating sectors of water resource management. However, the need is expected to expand to other sectors such as municipal and industrial water supply, waste water treatment, recreation, etc.

(b) acquire data sets not only on water-related events but also on those environmental parameters which impact or are influenced by these events e.g. atmospheric parameters and water quality parameters; and

It is becoming increasing apparent that the health of a country's economy is dependent on minimizing the degradation of the environment through socio-economic activity. In order to monitor the state of the environment, it will be necessary to acquire more data over a wider parameter spectrum. Hence a partially integrated data acquisition network is seen as a highly probable scenario for 1992.

(c) reduce or maintain network operating costs at present levels;

Provincial and federal government are pursuing a fiscal restraint policy which is expected to continue for the foreseeable future.

The above stated needs can be partially met through the installation of increasingly sophisticated sensors interfaced with micro-processor based data acquisition systems capable of transmitting data to the operator/user via any desirable communication system.

However, the application of high technology in itself is not sufficient. To maintain operating costs at near current levels, it will be necessary to automate data acquisition and automate effectively. Effective automation in terms of a hydrometric network operation requires that data acquisition both at the unattended hydrometric station and through activities conducted by field parties be viewed as components of a complete system.

Figure 5.1 is an illustration of an automated data acquisition system currently under development by the Water Resources Branch (WRB) of Environment Canada. The specific components and instruments comprising this system should be in operation by 1992. A description of instrumentation pertaining to hydrometric data acquisition is provided below:

5.1.1 Electronic Data Acquisition Systems (EDAS)

This can be considered the heart of an automated data collection program and the main development focus has been to produce an instrument through which the basic parameters defining a hydrological event can be monitored. These parameters are stage, slope and velocity. To maximize the benefits to the organization, data on these parameters must be acquired automatically and transmitted to the hydrometric station network operator in a time frame consistent with the hydrological event response characteristics. This will permit the operator to take the action required to maximize network performance.

In addition to hydrometric network operating requirements, pressures exerted by clients, the economy and politics demand that additional sensor interfacing capability be incorporated in the design criteria of the system. This has been taken into account. Figure 3.2 is an illustration of the design concept of the EDAS.

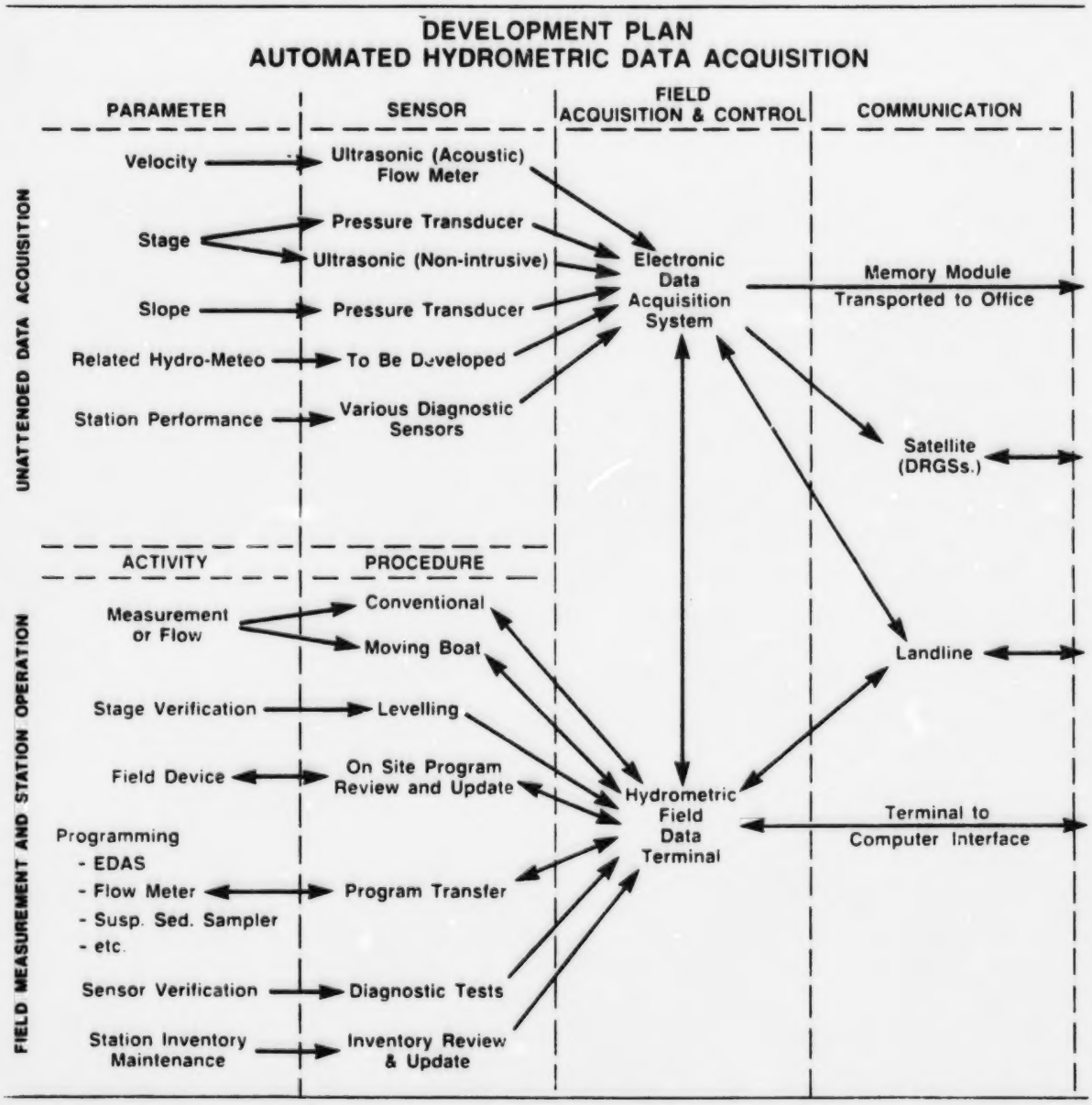

Figure 5.1 Development Plan - Automated Hydrometric Data Acquisition

5.1.2 Hydrometric Sensors

To make automation of hydrometric data collection feasible, the data collected at a station must provide sufficient information to permit the analytical reproduction of a hydrological event. The minimum parameters to be sensed under this criteria are stage, velocity and slope. Sensor development for each parameter is discussed below:

(1) Stage:

The stage sensing instrumentation development strategy is to improve flexibility and decrease complexity and cost of current stage sensing equipment. Two operating principles are under consideration, i.e. pressure sensing instruments and distance measuring devices using ultrasonics. The instruments using pressure sensing principles will be useable in either the submerged or non-submerged condition while ultrasonic devices will be primarily non-intrusive. Design characteristics of both sensors will be such that they meet WRB accuracy and reliability standards and that they are electronically compatible with the data acquisition system EDAS.

(2) Velocity:

WRB has investigated the potential of ultrasonic and electromagnetic flow measuring principles and instrumentation for application to its hydrometric network operation. Of the two, the ultrasonic flow meter is considered as the most applicable instrument for general network application. As a result, the decision was made to develop an ultrasonic flow meter which would operate under Canada's varied climate and have the capability to transfer data to an Electronic Data Acquisition System for transmission to regional offices. The flow meter is expected to provide near continuous data on flow velocity which when combined with stage and water surface slope, will define a flow event at a site to the extent required by the network operator and water resource manager at a cost acceptable to the network operating budget.

(3) Slope:

This is the last of the three parameters required to define a hydrological event at a station. This development will be an extension of the pressure transducer development project. The basic transducer design concept will be the same. However, the transducer will be submersible with both the high and low level parts of the transducer coupled to tubing of sufficient length to produce a measurable head difference between upstream and downstream orifices. The differential pressure thus generated will be a measure of the water surface slope.

5.1.3 Field Data Terminal and Field Measurements

Current hydrometric data reduction computation and archiving procedures are all conducted through the use of digital computers. The field flow measurement and note-keeping procedures, which have not changed appreciably since WSC began operation in 1908, are manual and hence have to be transcribed to achieve compatibility with computerized data handling procedures. Information not transcribed is difficult and time-consuming to access.

As plans for the development of the hydrometric flow measuring portable data terminal evolved, it became obvious that a portable microprocessor controlled data and information acquisition system could incorporate a number of required functions. These functions are indicated on Figure 5.2.

The collected data will be transferred from the electronic data acquisition system (EDAS) and the field data terminal to host computers directly or through an available data transmission system either satellite or ground-based. This tranfer is further illustrated in Figure 5.1.

By 1992, both satellite and ground base systems should have full two-way communication capability. This capability will be exploited to activate and deactivate sensors, change data acquisition and reporting frequency in line with demand for data on the event monitored. It is also likely that the integrity of sensors can be evaluated by remotely triggered diagnostic procedures. Thus, hydrometric site visits will be planned to coincide with specific network operation requirements and the network operator will realize an increase in net return for budget dollars expended.

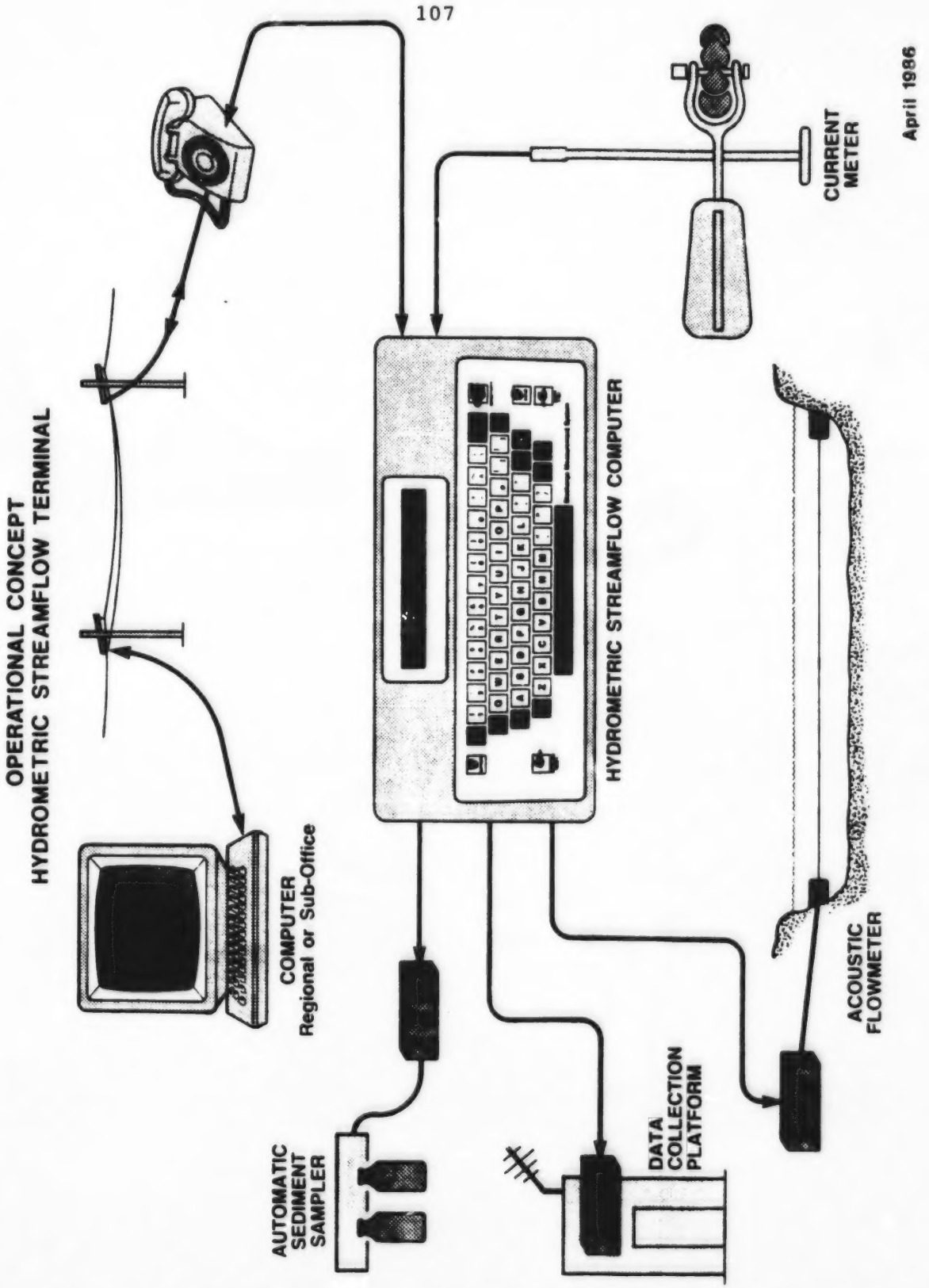

Figure 5.2 Operational Concept, Hydrometric Streamflow Terminal

5.2 THE NETWORK IN THE YEAR 2001

The trend to acquire environmental data through the operation of an automated, integrated data acquisition network, which should be in evidence by 1992, will continue. The driving forces behind this trend will be the same as those now in operation i.e. maintaining operating cost at a minimum, improving the range of available information with respect to the state of the environment, and improving the accessibility of that information.

5.2.1 Field Instrumentation

Micro-processor controlled sensors and data acquisition systems will increase substantially in performance capability, flexibility and reliability. Instrumentation costs should decrease with respect to parameter units sensed or as a minimum stay at current levels. As communication systems both satellite and land-based systems improve, the computer networking capability currently available for office computers will be extended to field installations. Hence, the network operator will have direct control over the functions performed by field installations from central control stations.

5.2.2 Network Operation

A fully integrated network approach to environmental data acquisition will greatly increase the complexity of network management. This complexity is caused by the variety of sampling strategies and data processing techniques which must be considered in the day-to-day operation of the network.

To permit network managers to function under these conditions, it is expected that artificial intelligence in the form of Expert Systems for network management will be implemented. The expert system(s) would be capable of analyzing the complex interactions of a cost-effective integrated network operation vis-a-vis data user requirements, thereby providing the network manager with the information required for effective decision making.

In the process of analyzing network operation, the system would be required to monitor the uncertainty and costs of the activities relevant to the data generating process. In so doing, it would ensure that timely, accurate, comprehensive, and cost-effective

data/information were provided to the environmental managers and user community in general in a time frame consistent with management requirements (e.g. real-time).

5.2.3 Data/Information Bases

Data generated through the operation of the network will reside in data bases whose access will be fully integrated with those containing related or supporting data/information e.g. data or information derived from remote sensing. This will provide the environmental manager with a broad base of information both in time and space.

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APPENDIX A

SITE-SPECIFIC CONSIDERATIONS

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SITE-SPECIFIC CONSIDERATIONS

Two network changes described below are indicated for selected stations in the following tables.

Network Change I

Change: An electronic water level instrument will be added to a site where a servo-manometer is presently in use. The electronic water level instrument will obtain measurements which can be compared to those obtained using the servo-manometer. Electronic data acquisition and recording system will be added when they are fully developed. When office procedures for electronic data handling are established, then servo-manometer will be withdrawn.

Phases:
- Phase 1 - Sensor placement at stations with D.C.P.'s.
- Phase 2 - Sensor placement at stations without D.C.P.'s after electronic data acquisition and storage units are fully operational. Replacement of analogue recorders by the electronic data acqusition and storage units.

Time Frames:
- Phase 1 - 1988 to 1992
- Phase 2 - 1992 to 1997

Network Change II

Change: An electronic water level instrument will be added to a site where a float-activated continuous analogue recorder presently exists. Electronic data acquisition and recording systems will be added when they are fully developed. When office procedures for electronic data handling are established, then the stilling wells and float-activated continuous analogue recorders will no longer be utilized.

Time Frame: 1994 to 1997

STATION NUMBER	STATION NAME	YEAR ESTAB.	COST SHARING CLASSIF.	INSTRUMENT-ATION	TYPE OF DATA	CONTROL	ACCESS	METHOD OF MEASUREMENT	D.A. km_2	REAL TIME	RECOM-MENDED CHANGE	CHANGE PRIORITY
01AD002	Saint John R. at Fort Kent	1926	P-3	Punch, Float	Q	5	2	Ice, Bridge	14700	D.C.P.		
01AD003	St. Francis R.	1951	P-3	A-35, Float	Q	3	3	Wading, Cableway, No B.W.	1350	D.C.P.	2 new D.C.P.	Med.
01AD004	Saint John R. at Edmundston	1967	P-3	A-35, Manometer	W.L.	N.A.	1	N.A.	15500	Tel.	I Ph. 2	Low
01AE001	Fish R. at Fort Kent	1903	P-3	Punch, Float	Q	3	1	Wading, Cableway	2260	Tel.		
01AF002	Saint John R. at Grand Falls	1930	P-3	A-35, Manometer	Q	3	2	Cableway, No B.W.	21900	Tel.	I Ph. 2	Med.
01AF003	Green R,	1962	P-2	A-35, Float	Q	5	1	Ice, Wading, Bridge	1150	Tel.	II	Med.
01AF007	Grande Riviere	1976	P-P-3	A-35, Manometer	Q	5	1	Ice, Wading, Bridge	339	D.C.P.	I Ph. 1	Med.
01AG002	Limestone Stream	1967	P-3	A-35, Float	Q	7	2	Ice, Wading, Cableway	199	Tel.	II	Low
01AG003	Aroostook R.	1974	P-3	A-35, Manometer	Q	3	3	Wading,Cableway, No. B.W.	6060	Tel.	I Ph. 2 Tel.2 or D.C.P.	Med.
01AH002	Tobique R. at Riley Brook	1954	P-2	A-35, Float	Q	5	1	Ice, Wading, Bridge	2230	Tel.	II	Low
01AH003	Tobique R. at Plaster Rock	1954	P-2	A-35, Float	Q	5	1	Ice, Wading Bridge	3130	Tel.	II	Low
01AH004	Tobique R. at Narrows	1953	Other	-	Q	-	-	Plant releases	4330			

STATION NUMBER	STATION NAME	YEAR ESTAB.	COST SHARING CLASSIF.	INSTRUMENT-ATION	TYPE OF DATA	CONTROL	ACCESS	METHOD OF MEASUREMENT	D.A. km_2	REAL TIME	RECOM-MENDED CHANGE	CHANGE PRIORITY
01AH005	Mamozekel R.	1972	F-P-3	A-35, Float	Q	5	3	Ice, Wading Bridge	230	D.C.P.	II	Low
01AJ001	Saint John R. at Florenceville	1951	F-4	A-35, Manometer	Q	4	1	Moving Boat, Boat, No B.W.	34200	Tel.	I Ph.2 Tel.2 or D.C.P.	Med.
01AJ003	Meduxnekeag R.	1967	F-3	A-35, Float	Q	5	2	Ice, Wading Cableway	1210	Tel.	II	Med.
01AJ004	Big Presque Isle Str.	1967	F-3	A-35, Float	Q	5	2	Ice, Wading Cableway	484	Tel.	II	Low
01AJ008	Saint John R. at Hartland	1973	F-P-2	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Tel.	I Ph.2 Tel.2 or D.C.P.	Med.
01AJ009	Saint John R. at Simonds	1974	F-1	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Tel.	I Ph.1	Low
01AJ010	Becaguimec Stream	1973	F-P-3	A-35, Float	Q	5	1	Wading, Bridge No B.W.	350	Tel.	II	Low
01AJ011	Cold Stream	1973	F-P-3	A-35, Float	Q	10	1	Wading, Bridge, No B.W.	156	Tel.	II	Low
01AK001	Shogomoc Stream	1918	F-P-3	A-35, Float	Q	3	4	Ice, Wading, Cableway	234	D.C.P.	II New D.C.P.	Low
01AK003	Saint John R. at Fredericton	1960	F-4	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Tel.	Footnote No. 1	
01AK004	Saint John R. below Mactaquac	1961	F-4	A-35, Manometer	Q	7	1	Moving boat, Conventional boat-	39900	Tel.	Footnote No. 2	
01AK005	Mid. Br. Nashwaaksis Str. at Royal Road	1965	F-P-3	A-35, Float	Q	7	1	Wading, Bridge, No B.W.	26.9	N.A.	II	Low

Footnote No. 1 It is suggested to convert this station to a discharge station. High priority should be given to installation of a data collection platform and an ultrasonic velocity measurement device.

Footnote No. 2 Flow measurements may no longer be required if Mactaquac can be rated for higher range of flow. The need for moving boat or conventional boat measurement will be reduced. The station can be converted to stage only.

STATION NUMBER	STATION NAME	YEAR ESTAB.	COST SHARING CLASSIF.	INSTRUMENT-ATION	TYPE OF DATA	CONTROL	ACCESS	METHOD OF MEASUREMENT	D.A. km_2	REAL TIME	RECOM-MENDED CHANGE	CHANGE PRIORITY
01AK006	Mid. Br. Nashwaaksis Str. at Sandwith's Farm	1966	F-P-3	A-35, Float	Q	4	1	Wading, No B.W.	5.70	N.A.	II	Low
01AK007	Nackawic Stream	1967	F-P-3	A-35, Manometer	Q	7	1	Ice, Wading, Bridge	240	Tel.	I Ph.2 Tel.2 or D.C.P.	Low
01AK008	Eel R. at Scott Siding	1974	F-P-3	A-35, Float	Q	5	5	Ice, Wading, Cableway	531	Tel.	II	Low
01AK009	Saint John R. at Mactaquac Gen. Stn.	1980	F-P-2	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Tel.	I Ph.2 Tel.2 or D.C.P.	Low
01AL002	Nashwaak R. at Durham Bridge	1961	F-P-3	A-35, Float	Q	4	1	Ice, Wading, Bridge	1450	Tel.	II	Low
01AL003	Hayden Brook	1970	F-1	A-35, Manometer	Q	7	3	Wading, No winter m.m.	6.48	N.A.	I Ph.2	Low
01AL004	Narrows Mountain Brook	1972	F-1	A-35, Manometer	Q	7	2	Wading, No winter m.m.	3.89	N.A.	I Ph.2	Low
01AL008	Nashwaak R. at Stanley	1982	P-2	A-35, Manometer	Q	5	1	Ice, Wading, Bridge	641	Tel.	I Ph.2 Tel.2 or D.C.P.	Low
01AM001	N. Br. Oromocto R.	1962	F-P-3	A-35, Float	Q	5	1	Ice, Wading, Bridge	557	Tel.	II	Med.
01AN001	Castaway Stream	1972	F-P-3	A-35, Float	Q	7	1	Ice, Wading, Bridge	34.4	N.A.	II	Low
01AN002	Salmon R. at Castaway	1974	F-P-3	A-35, Manometer	Q & P	5	3	Ice, Wading, Boat	1050	D.C.P.	I Ph.2 New D.C.P.	Med.
01A0002	Saint John R. at Maugerville	1965	P-2	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Tel.	I Ph.2 Tel. 2 or D.C.P.	High

STATION NUMBER	STATION NAME	YEAR ESTAB.	COST SHARING CLASSIF.	INSTRUMENT-ATION	TYPE OF DATA	CONTROL	ACCESS	METHOD OF MEASUREMENT	DA. km_2	REAL TIME	RECOM-MENDED CHANGE	CHANGE PRIORITY
01AØ003	Grand Lake	1965	P-2	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Tel.	I Ph.2 Tel.2 or D.C.P.	Low
01AØ004	Jemseg R.	1966	F-1	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Tel.	I Ph.2 Tel.2 or D.C.P.	Low
01AØ009	Burpee Millstream	1976	F-P-3	A-35, Manometer	Q	7	3	Ice, Wading, Cable follower	93.2	N.A.	I Ph.2	Low
01AØ010	French Lake	1980	P-2	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Tel.	I Ph.2 Tel.2 or D.C.P.	Low
01AP002	Canaan R.	1925	F-P-3	A-35, Float	Q	5	1	Ice, Wading, Bridge	668	Tel.	II	Low
01AP003	Saint John R. at Oak Point	1923	F-1	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Tel.	I Ph.1	Low
01AP004	Kennebecasis R.	1961	F-P-3	A-35, Manometer	Q	4	1	Ice, Wading, Bridge	1100	Tel.	I Ph.2 D.C.P.	Med.
01AP005	Saint John R. at Saint John	1966	F-1	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	Tel.	I Ph.2 Tel.2 or D.C.P.	Med.
01AP006	Nerepis R.	1976	F-P-3	A-35, Float	Q	5	3	Ice, Wading, Cableway	293	N.A.	II	Low
01AQ001	Lepreau R.	1916	F-4	A-35, Float	Q	5	1	Ice, Wading, Cableway	239	Tel.	II	Low
01AQ002	Magaguadavic R.	1917	F-4	A-35, Manometer	Q	3	2	Ice, Wading, Cableway	1420	N.A.	I Ph.2	Low
01AQ007	Magaguadavic Lake	1978	P-2	A-35, Manometer	W.L.	N.A.	3		N.A.	N.A.	I Ph.2	Low
01AQ008	Piskahegan Stream	1982	F-P	A-35, Manometer	Q	3	2	Ice, Wading, Cableway	197	D.C.P.	I Ph.2	Low

STATION NUMBER	STATION NAME	YEAR ESTAB.	COST SHARING CLASSIF.	INSTRUMENT-ATION	TYPE OF DATA	CONTROL	ACCESS	METHOD OF MEASUREMENT	D.A. km_2	REAL TIME	RECOM-MENDED CHANGE	CHANGE PRIORITY
01AQ009	Lake Utopia	1985	P-2	A-35, Manometer	W.L.	N.A.	1	N.A.	N.A.	N.A.	I Ph.2	Low
01AR004	St. Croix R. at Vanceboro	1928	F-3	Punch, Manometer	Q	3	1	Wading, Cable-way, No. B.W.	1080			
01AR005	St. Croix R. at Baring	1959	F-3	Punch, Float	Q	3	1	Cableway, No B.W.	3550			
01AR006	Dennis Stream	1966	F-4	A-35, Float	Q	5	1	Ice, Wading, Bridge	115	D.C.P.	II	Low
01AR009	Grand Lake at Forest City	1969	F-3	A-35, Float	W.L.	N.A.	1	N.A.	N.A.	N.A.	II	Low
01AR010	Spednic Lake	1967	F-3	A-35, Float	W.L.	N.A.	1	N.A.	N.A.	N.A.	II	Med.
01AR011	Forest City Stream	1969	F-3	A-35, Float	Q	5	2	Wading, Cableway, No B.W.	357	N.A.	Tel.2 2 Real Time	Low
01AR012	Chamcook Stream	1968	F-P-2	A-35, Float	Q	5	2	Wading, No B.W.	N.A.	N.A.	Footnote No. 3	
01AR013	Grand Falls Flowage	1980	F-3	A-35, Float	W.L.	N.A.	1	N.A.	N.A.	N.A.	II	Low
01BC001	Restigouche R. at Kedgwick	1962	F-2	A-35, Float	Q	3	2	Ice, Wading, Boat	3160	N.A.	II	Low
01BE001	Upsalquitch R.	1918	F-4	A-35, Float	Q	3	1	Ice, Wading, Bridge	2270	D.C.P.	II	Low
01BJ001	Tetagouche R.	1923	F-4	A-35, Manometer	Q	4	4	Ice, Wading, Bridge	363	N.A.	I Ph.2	Low
01BJ003	Jacquet R.	1964	F-4	A-35, Float	Q	5	4	Ice, Wading, Bridge	510	N.A.	II	Low

Footnote No. 3 Relocation of station 01AR012 suggested a drainage area not defined for high flows. Data needs should be clarified.

STATION NUMBER	STATION NAME	YEAR ESTAB.	COST SHARING CLASSIF.	INSTRUMENT-ATION	TYPE OF DATA	CONTROL	ACCESS	METHOD OF MEASUREMENT	D.A. km^2	REAL TIME	RECOM-MENDED CHANGE	CHANGE PRIORITY
01BJ007	Restigouche R. at Raft. Grd. Brk.	1968	F-4	A-35, Manometer	Q	3	1	Ice, Boat (2 technicians)	7740	D.C.P.	I Ph.1	Med.
01BJ009	Walker Brook	1980	P-2	A-35, Float	Q	5	1	Ice, Wading, Cableway	60.8	N.A.	II	Low
01BJ011	Nigadoo R.	1981	P-2	A-35, Manometer	Q	5	3	Ice, Wading, Cableway	123	N.A.	I Ph.2	Low
01BJ012	Eel R. at Dundee	1983	F-P-3	A-35, Manometer	Q	5	2	Ice, Wading, Bridge	43.2	N.A.	I Ph.2	Low
01BK003	Nepisiquit R.	1921	Other	-	Q	-	-	Plant releases	1840			
01BK006	Forty Mile Brook	1981	F-P-3	A-35, Manometer	Q	6	5	Wading, Bridge No B.W.	13.0	N.A.	I Ph.2	Low
01BJ010	Middle R.	1981	P-2	A-35, Manometer	Q	5	1	Ice, Wading, Cableway	190	N.A.	I Ph.2	Low
01BL001	Bass R.	1965	F-4	A-35, Float	Q	6	3	Ice, Wading, Bridge	175	N.A.	II	Low
01BL002	Riviere Caraquet	1969	F-4	A-35, FLoat	Q	5	2	Ice, Wading, Bridge	173	N.A.	II	Low
01BL003	Big Tracadie R.	1970	F-4	A-35, Float	Q	5	5	Ice, Wading, Cableway	383	D.C.P.	II	Low
01BØ001	S.W. Miramichi R.	1918	F-4	A-35, Manometer	Q	3	1	Ice, Wading, Bridge	5050	Tel.	I Ph.2 Tel.2 or D.C.P.	Low
01BØ003	Barnaby R.	1973	F-P-3	A-35, Float	Q	5	4	Ice, Wading, Cableway	484	N.A.	II	Low

STATION NUMBER	STATION NAME	YEAR ESTAB.	COST SHARING CLASSIF.	INSTRUMENT-ATION	TYPE OF DATA	CONTROL	ACCESS	METHOD OF MEASUREMENT	D.A. km_2	REAL TIME	RECOM-MENDED CHANGE	CHANGE PRIORITY
01B∅002	Renous R.	1965	F-P-3	A-35, Float	Q	5	2	Ice, Wading, Cableway	611	N.A.	II	Low
01B∅004	Bartibog R.	1978	F-P-3	A-35, Float	Q	5	3	Ice, Wading, Cableway	316	N.A.	II	Low
01BP001	L.S.W. Miramichi R.	1951	F-P-3	A-35, Manometer	Q	5	1	Ice, Wading, Bridge	1340	N.A.	I Ph.2	Low
01BQ001	N.W. Miramichi R.	1961	F-P-3	A-35, Float	Q	4	1	Ice, Wading, Cableway	948	D.C.P.	II	Low
01BR001	Kouchibouguac R.	1930-33 1969	F-4	A-35, Float	Q	4	1	Ice, Wading, Bridge	177	N.A.	II	Low
01BS001	Coal Branch R.	1964	F-4	A-35, Float	Q	5	1	Ice, Wading, Bridge	166	N.A.	II	Low
01BT001	Kinnear R.	1985	F-P-3	A-35, Float	Q	6	1	Ice, Wading, Bridge	32.1	N.A.	II	Low
01BU002	Petitcodiac R.	1961	F-4	A-35, Float	Q	7	1	Ice, Wading, Bridge	391	N.A.	II	Low
01BU003	Turtle Creek	1962	P-2	A-35, Float	Q	6	1	Ice, Wading, Bridge	129	N.A.	II	Low
01BV006	Point Wolfe R.	1964	F-1	A-35, Manometer	Q	6	4	Wading, Cableway, Ice	130	D.C.P.	I Ph.1	Med.

APPENDIX B

DATA QUALITY INDEX

APPENDIX B

DATA QUALITY INDEX

This technique has been developed to quantify the quality of the discharge data produced for each gauging station. It will give confidence weights to open water flows, winter backwater flows, estimated flows and flows affected by shift corrections. The final value obtained for the station will be used to do relative comparisons with other stations and to target stations whose output could be improved.

1. The first step is to examine the station's stage discharge curves to determine the range for which the present curve (1983) is valid. In order to do this it will be necessary to compare the latest curve with the ones before and establish which portions of the previous curves are still defined by the present stage-discharge relationship. In some cases when there is a complete, parallel shift, all previous curves and any of their measurements will have to be eliminated. In some other cases where only the lower portions of the curve shifted, the upper ranges of the curves being compared will converge. The discharge measurements taken in this range are still valid in defining the present stage discharge relationship.

   Example

   A station has five curves. Curve No. 5 is in effect from 1980. Range is 1.2 m to 3.7 m. In 1980 the bottom end of Curve No. 4 shifted between 1.2 m to 1.5 m range. All other measurements on the Curve No. 4 above 1.5 m up to 3.9 m are still valid. In 1978 Curve No. 3 shifted in the 1.3 to 2.7 range. All measurements above the 2.7 m range are still defining the present curve. In 1975, there was severe scouring and the whole curve from 1.1. m to 4.0 m shifted. This means that previous measurements, even historical lows or highs no longer define the present curve. From the above information, it can be determined that the maximum and minimum range for the present curve is between 1.2 m and 3.9 m. All measurements above 2.7 m down to 1975, above 1.5 m down to 1978, and all measurements down to 1980 can be used.

Example

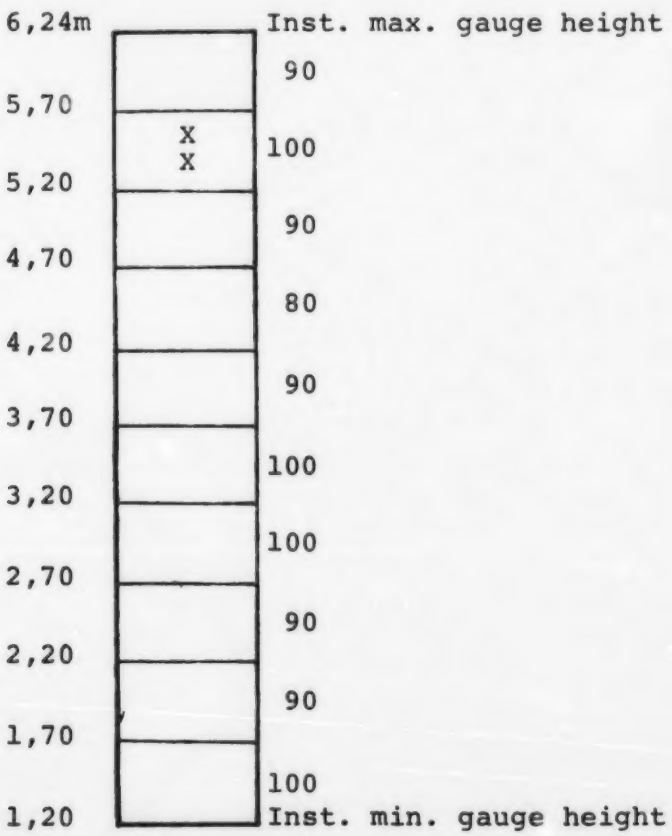
Instantaneous Max: gauge height = 6.24 m
Instantaneous Min: gauge height = 1.20 m

Range for the present stage discharge relationship is 6.24 - 1.20 = 5.04 m.

2. Plot these heights on a suitable vertical scale and divide into 10 equal blocks (deciles).

3. Plot on this scale all gauge heights of measurements that are used to determine the stage discharge curve currently in use. A list of the measurements which pertain to the present curve can be extracted from the file of discharge measurements created by the NEED Program. Those that are in Imperial units will have to be converted to metric units. The validity of the measurements which qualify in the definition of the curve will already have been established in Step 1. Suffice to make a list of them with their water level (WL), the discharge measured (Qm), the corresponding relationship curve discharge (Qr) and the deviation in percentage of Qm from Qr.

Example



4. Every block (decile) that has at least one valid discharge measurement will be assigned a full value: 100. Blocks with no measurement but with at least one adjacent block with one measurement will be assigned a value of 90. Three consecutive blocks with no measurements would be given respective values of 90, 80 and 90. Four consecutive blocks with no measurements would be assigned of 90, 80 and 90. And so on .....

   From this point there could be several ways to proceed but it was found by experience that the following way was the most efficient one. Use the 1983 annual printouts, both discharge and water level. From the discharge printout it is possible to extract the periods of record under backwater due to ice cover. The value given to the B-days will be a function of the consecutive days between two open water periods and/or discharge measurements. A-days will be counted as open water record. A scale has been developed to weigh the backwater periods. The number of days in a period of continuous backwater will be counted and multiplied by the proper scale value.

TABLE 1

BACKWATER

BW Days	Weight Factor
1-2	90
3-10	80
11-30	70
31-60	60
61-90	50
91-365	40

Example

Let us say we have 140 days of BW due to ice cover. The ice sets in on December 1 and leaves April 25 with a six (6) day open water period from December 26 to December 31. Discharge measurements are taken - January 15, February 8 and March 23.

			Weight Factor
December 1	to December 25	- 25 days	70
December 26	to December 31	- 6 days (open water)	--
January 1	to January 14	- 14 days	70
January 15	to	- 1 day	100
January 16	to February 8	- 24 days	70
February 9	to	- 1 day	100
February 10	to March 22	- 41 days	60
March 23	to	- 1 day	100
March 23	to April 25	- 33 days	60

5. To facilitate the technique if there had been some missing record during BW days, the "BW" factor would override the "E" factor. An example of this would have been a clock stoppage for 10 days. The "E" factor would have given the record a weight of 60 while the "BW" factor will give it a weight of 80.

   Once the data are properly weighted, they are summed up.

   $\Sigma B = (25 \times 70) + (14 \times 70) + 1 \times 100) + (24 \times 70) + (1 \times 100) + (41 \times 60) + (1 \times 100) + (33 \times 60) = 9150$

   $\Sigma_B = 9150$

6. The next step is to apply weights to the days of record affected by shift corrections. The shift corrections have to be extracted from the pink updating sheet. The same principle applies for shift data as for backwater data. A scale, shown below, will be used to weight uninterupted periods of shift corrections. The weight applied is function of the length of period.

TABLE 2

SHIFT CORRECTION SCALE

Consecutive Days with Shift Correction Applied	Weight Factor
1 - 10	90
11 - 30	80
31 - 50	70
51 - 60	60
61 - 365	50

Example

In this case we have 10 continuous days with a graduated shift correction. Weight factor would be 90.

10 x 90 = 900

Example

If you had an extended period with a shift correction applied, the approach used would be the same as the one used for BW correction.

Let us say that due to weed growth a shift correction was applied from June 10 to October 2 with measurements taken on July 6, August 15, September 2 and October 10.

		Factor
June 10	discharge measurement	100
June 11 - July 5	25	80
July 6	discharge measurement	100
July 7 - August 14	39	70
August 15	discharge measurement	100
August 16 - September 1	17	80
September 2	discharge measurement	100
September 3 - October 9	37	70
October 10	back on curve (treated as open water)	100

Periods of shift record would be multiplied by their respective weighing factor and then summed up.

7. The following step is to assign weights to the estimated periods of record (E-days). The values given to the E-days will be function of the period of consecutive days between two open water periods (or in some cases, discharge measurements). It should be pointed out that A-days will be considered as open water days and will be assigned the proper decile value. The annual printouts can be used to extract

the periods of missing record. The following weight scale has been developed for E-days.

Table 3	Missing Days	Weight Factor
	1	90
	2-3	80
	4-6	70
	7-10	60
	11-30	50
	31-365	40

Use the scale to assign the proper weights to the periods of missing record. Multiply periods by assigned weights and sum up.

Example (There are five (5) periods of missing record)

3 (1 day period missing record)
1 (6 day period missing record)
1 (8 day period missing record).

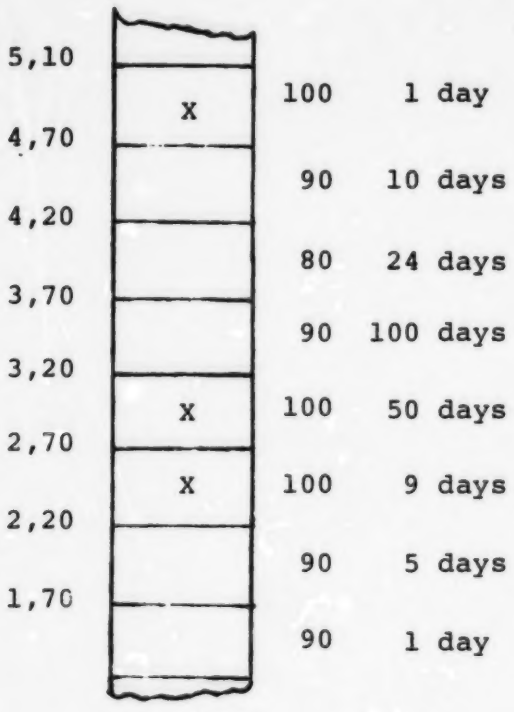
(3 x 1 x 90) + (6 x 70) + (8 x 60) = 1170

8. As previously mentioned, A-days are to be treated as open water days. However, the water level of A-days is not included on the printout. Using the 1983 stage discharge relationship, determine the corresponding water level of the A-days. Once these water levels are known and listed, they can be treated the same way as the other open water record.

9. Examine the 1983 annual printout - Using this printout, count the number of open water days which correspond to a given gauge height block (example 50 days between 3.20 m and 3.70 m) and multiply by the corresponding weight. (In this case 50 days x 100 = 5000). If there are nine (9) days between the guage height of 3.70 and 4.20, a weight factor of 90 will be assigned to each day in question (9 day x 90 = 810). All other open water days should be assigned their proper numerial weight.

   N.B. It should be pointed out that the open water days are not to include the estimated days (E-days) and days affected by Shift corrections. A-days will be considered as open water days and given the full value of the decile.

10. All blocks of open water days multiplied by their proper weight will be summed up.
Example



$$\Sigma \text{open} = (1 \times 100) + (10 \times 90) + (24 \times 80) + (100 \times 90) + (50 \times 100) + (9 \times 100) + (5 \times 90) + (1 \times 90)$$

$$\Sigma \text{open} = 19{,}360$$

11. The next step in determining the quality index of the station record is to further refine the open water assessment by examining the scatter of the discharge measurements used to establish the stage discharge relationship. An index of overall scatter is obtained in the following way:

a) Examining the 1983 stage discharge curve and previous curves, a list of all measurements contributing to the definition of the H - Q relationship was obtained. The present system

for filing the stage discharge curves dates back to the early 1960's. For practical reasons, measurements were only included up to that date. If portions of the curve are only defined by earlier measurements, then earlier measurements can and should be used. Care should be taken not to include measurements which are no longer valid for the curve presently in use.

12. The deviation of each measurement with the H-Q curve was computed previously when the range of the present curve was determined. Any measurement with a deviation of less than 5% is assigned a full value - 100. Measurements who deviate between 5% or 10% will obtain a value of 50. Measurements that are more than 10% off the curve will receive a value 0. Once all measurements are assigned their proper weight, they are summed up and then divided by the total number of measurements. This gives us a scatter weight factor.

Example

Let us say we have 12 measurements which qualify. Seven (7) measurements deviate by less than 5%. Another 4 deviate between 5 and 10%. Another measurement is 12% off the curve.

$$\text{S.F. (Scatter Factor)} = \frac{7 \times 100 + 4 \times 50}{12} = \frac{900}{12} = 75$$

13. The scatter factor is applied to the open water sum. Using the value obtained for the open water example:

$$\Sigma^1 \text{open} = \Sigma \text{open} \times \text{S.F.} = 19360 \times 0.75$$
$$\Sigma^1 \text{open} = 14520$$

14. The final step in establishing the station's Data Quality Index/

$$\text{Q.I. (Quality Index)} = \frac{\Sigma^1 \text{open} + \Sigma \text{Est} + \Sigma \text{Bw} + \Sigma \text{Sh}}{365}$$

$$= \frac{14520 + 1170 + 9150 + 900}{365}$$

$$= 71$$